

N O T I C E

THIS DOCUMENT HAS BEEN REPRODUCED FROM
MICROFICHE. ALTHOUGH IT IS RECOGNIZED THAT
CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED
IN THE INTEREST OF MAKING AVAILABLE AS MUCH
INFORMATION AS POSSIBLE

"Made available under NASA sponsorship
in the interest of early and wide dis-
semination of Earth Resources Survey
Program information and without liability
for any use made thereof."

81-10158
0TR-164267

SEMI-ANNUAL STATUS REPORT
of the
NASA-sponsored
Cornell University Remote Sensing Program
June 1 - November 30, 1980

81-25454
THRU
81-25461
UNCLAS
00153

NASA Grant NGL 33-010-171

83/43
CORNELL UNIVERSITY REMOTE
SENSING PROGRAM Semiannual Status Report, 1
(81-10153) Cornell Univ., CSCI 05B
JUN. - 30 NOV. 1980 (Cornell Univ., Ithaca,
N. Y.) 375 P HC A16/RF A01

Original photography may be purchased from:
EROS Data Center
Sioux Falls, SD 57198

Principal Investigator: Ta Liang
Co-Investigator: Warren R. Philipson
Research Associate: John A. Stanturf

Remote Sensing Program
Cornell University
Hollister Hall
Ithaca, New York 14853

December 1980





REMOTE SENSING PROGRAM
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
HOLLISTER HALL
ITHACA, NEW YORK 14853
(607) 256-4330, 256-5074

December 18, 1980

NASA Scientific and Technical
Information Facility
P.O. Box 8757
Baltimore-Washington International Airport
Maryland 21240

Subject: NASA Grant NGL 33-010-171

Gentlemen:

In accordance with the provisions of the subject grant, we are transmitting herewith two (2) copies of our 17th Semi-Annual Status Report, covering the period June 1 to November 30, 1980. In addition, three (3) copies of this report are being sent directly to the Technology Transfer Division, NASA Headquarters, Washington, D.C. 20546 (Attention: Mr. J.A. Vitale).

Sincerely yours,

Ta Liang
Ta Liang
Principal Investigator

TL/pw

cc: Mr. J.A. Vitale, NASA Headquarters
Mr. D.A. Douvarjo, NASA Headquarters
Deans T.E. Everhart and D.P. Loucks
Mr. T.R. Rogers and Mr. F.J. Feocco
Director R.N. White

LIST OF APPENDICES

- A. Fuelwood Availability for a Ten Megawatt Power Plant in Tupper Lake, N.Y., Based on Remotely Sensed and Other Data
- B. Inventory of Coniferous Forests Near Bath, N.Y.
- C. A Comparative Study of Small Scale Remotely Sensed Data for Monitoring Clearcutting in Hardwood Forests.
- D. Assessment of Potential Industrial Sites in Essex County, N.Y.
- E. Research Papers
- F. Selected Correspondence
- G. Recent Newsletters
- H. Newsletter Recipients

INTRODUCTION

The primary objective of the NASA-sponsored, Cornell University Remote Sensing Program is to promote the application of aircraft and satellite remote sensing, particularly, in New York State. In accordance with NASA guidelines, this is accomplished through conferences, seminars, instruction, newsletters, news releases, and most directly, through applied research projects. Each project must be, in some way, unique; essentially noncompetitive with commercial firms; and potentially, benefit- or action-producing. Relatively little emphasis is placed on technology transfer, per se.

The activities of the Remote Sensing Program staff, from June 1 to November 30, 1980 are reviewed in this Semi-Annual Status Report, the seventeenth to be submitted to NASA since the Program's inception in June 1972.

COMMUNICATION AND INSTRUCTION

Contacts and Cooperators

Communication is vital to the success of Cornell's Remote Sensing Program. The Program staff spends many hours discussing remote sensing with representatives of various federal, state, regional, county and local agencies, public and private organizations, the academic community and foreign countries.

Over the past six months, members of the Program staff have presented three research papers. These papers were well received, stimulating discussion and subsequent requests for reprints from around the country. A paper on the use of "historic" airphotos to analyze landfills was presented at the American Society of Civil Engineers/American Society of Photogrammetry Specialty Conference on Civil Engineering Applications of Remote Sensing. Two papers were given at the American Society of Photogrammetry Fall Technical Meetings in Niagara Falls. One was a comparison of manual and digital analyses of Landsat for modeling river flooding, and the second an approach to environmental impact assessment using remote sensing (Appendix E).

Along with receiving project cooperators from the Planning Department of Hamilton County, the N.Y.S. Department of Health, the St. Regis Paper Company office at Deferiet, N.Y., the N.Y.S. Department of Commerce, and other Cornell departments, Program staff provided remote sensing consultations or orientations to some 35 members of the Central New York Region, American Society of Photogrammetry, to student groups from the State University of New York at Binghamton and the State University of New York at Brockport, and to representatives of the N.Y.S. Cooperative Wildlife Research Unit, the U.S. Fish and Wildlife Service, the U.S. Agency for International Development, the U.S. Environmental Protection Agency's Environmental Monitoring Systems Laboratory, and the Instituto Nacional de Investigacion, Corporacion de Fomento (IREN/CORFO), Chile.

Of special note is that, under a grant to Cornell from the Environmental Protection Agency, the co-investigator participated in a peer review of programs of the EPA's Environmental Monitoring Systems Laboratory. He visited and was responsible for reviewing the remote sensing activities of the Las Vegas center and the Environmental Photo Interpretation Center (EPA/EPIC) in Warrenton, Va.

As in the past, many new and continuing dialogs were also held via the mail and telephone (Appendix F). These were often in response to requests for remote sensing consultations (e.g., Eastman Kodak regularly refers requests for advice on remote sensing applications to the Program; the N.Y.S. Department of Environmental Conservation requested advice, via telephone, on the use of remote sensing for monitoring gypsy moth infestation); but several were of value in developing new remote sensing projects.

Newsletters

The Program's "Cornell Remote Sensing Newsletter" continues to serve as an important link to and beyond the Cornell community (Appendix G). By highlighting remote sensing activities at Cornell while reporting other items of interest, the Newsletter has attracted a readership which greatly exceeds the mailing list of more than 550 individuals or groups in over 40 states and 20 countries (Appendix H).

Seminars

The weekly Seminar in Remote Sensing, sponsored for nine years by the Program, has provided students, staff, and other interested individuals at Cornell the opportunity to discuss remote sensing topics with experts from government, industry, and other institutions. The Seminar was not held during the fall semester, 1980, but planning for the spring semester is well underway. Speakers from the N.Y.S. College of Environmental Science and Forestry, NOAA/NESS, and the U.S. Army Coastal Engineering Research Center have been scheduled, and others have been invited.

Courses, Special Studies and Workshops

The 1980-1981 course offerings emphasize remote sensing technology, which is synonymous with NASA. As described in the previous report, three of the six formal courses in the revised curriculum were developed under the NASA grant.

During the past six months, four graduate theses were completed under Program staff supervision: Remote sensing studies of some ironstone gravels and plinthite in Thailand (Ph.D., Pichit Jamnongpipatkul); Development of a remote sensing methodology for range-land monitoring in Botswana (M.S., Elaine S. Aderhold); A comparative study of small scale remotely sensed data for monitoring clear-

cutting in hardwood forests (M.S., William R. Hafker); and Assessment of potential industrial sites in Essex County, N.Y. (M.E. Civil, Thomas M. Wozny). The latter two studies have received direct financial support from the NASA grant, and they are included in Appendices C and D. Ongoing graduate thesis investigations include: Remote sensing for engineering properties of arid region landforms (Ph.D., William L. Teng); Remote sensing of river ice (M.S., Thomas L. Erb); and Remote sensing for vineyard management and yield estimation (M.S., Katherine A. Minden). Three other graduate students are in the early stages of defining thesis topics.

DATA AND FACILITIES

As described in earlier reports, staff research and instruction have been enhanced through continued acquisition of a wide range of remotely sensed, aircraft and satellite data, and through extension of capabilities for their analysis and interpretation. These data, along with Program facilities and equipment, are made available at no cost to cooperators, students and other interested users.

With assistance from the NASA Office of University Affairs, the Program has received Landsat, Skylab, high altitude and low altitude coverage of sites in the Northeast, and an aircraft multispectral scanner mission was flown in September 1980. The U.S. Environmental Protection Agency has also overflowed Program-selected sites at no cost to the Program; and imageries have been obtained from the U.S.A.F. Rome Air Development Center, the U.S. Geological Survey, the U.S. Department of Agriculture, the St. Lawrence Seaway Development Corporation, the National Air Photo Library of Canada, the Tri-State Regional Planning Commission, the National Archives, Eastman Kodak Company and several commercial mapping firms. In addition, the NASA Johnson Space Center recently supplied the Program with copies of selected surplus films.

The Program maintains or has access to spectroradiometers and selected image analysis equipment (i.e., zoom and non-zoom stereoscopes, density slicer, color-additive viewer, monoscopic and stereoscopic Zoom Transfer Scopes, densitometer and other photographic instruments). The Program also has an active file of computer routines for analyzing multispectral digital data. These routines have received increased usage in Program-sponsored, spin-off and thesis investigations with Landsat and aircraft scanner data. Additionally, the Program's computer routines for analyzing Landsat tapes have been used by researchers at the N.Y.S. College of Environmental Science and Forestry, and the State University of New York at Binghamton, the latter, via a telephone link.

To increase the Program's image analysis capability, the staff recently submitted a proposal to the National Science Foundation for the acquisition of interactive digital equipment. Costs would be shared equally by NSF and Cornell. Action on this proposal will be known by March 1981.

PROJECTS COMPLETED

During the six month period, June 1, 1980 to November 30, 1980, the Cornell Remote Sensing Program staff completed one applied research project and one assistance project. As noted, one Master of Science thesis and one Master of Engineering (Civil) design project were also conducted with financial support from the NASA grant.

Applied Research Project:

1. Fuelwood availability for a ten megawatt power plant in Tupper Lake, N.Y., based on remotely sensed and other data.

Assistance Project:

2. Inventory of coniferous forests near Bath, N.Y.

Thesis/Design Projects:

3. A comparative study of small scale remotely sensed data for monitoring clearcutting in hardwood forests.
4. Assessment of potential industrial sites in Essex County, N.Y.

The projects are summarized here, and pertinent material on each is included in an appendix.

1. *Fuelwood availability for a ten megawatt power plant near Tupper Lake, N.Y., based on remotely sensed and other data*

Uncertainty in petroleum cost and supply has prompted interest in alternative energy sources such as wood. The New York State Energy Office is considering development of a ten megawatt wood-fired power plant in the Adirondack region. A primary consideration is the availability of sufficient woody material to fuel the plant. Through analysis of NASA high altitude, color infrared aerial photographs and Landsat images, Program staff delineated forested land potentially available for fuelwood harvest within 20 km of Tupper Lake, N.Y., and classified the forested land as to forest type: deciduous, coniferous, or mixed. Published inventory and growth data were used to estimate woody material on the available land. The information submitted to the Energy Office indicated that there is sufficient woody material to supply a 10 MW plant. The fuelwood estimates will be used in further analysis of the plant's economic feasibility by consultants to the Energy Office and the Power Authority of the State of New York.

2. *Inventory of coniferous forests near Bath, N.Y.*

A particleboard manufacturing firm is considering constructing a new plant in the Southern Tier near Bath, N.Y. A primary factor in assessing the feasibility of the plant is the supply of conifers and low-density hardwoods. Available forest resource information is aggregated (the smallest unit for which data are reported is

the county) and dated (New York--1970 , Pennsylvania--1965). At the request of a consultant to the N.Y.S. Department of Commerce, Program staff used NASA high altitude, color infrared aerial photographs and Landsat imagery to inventory coniferous forests within 50 miles of Bath, N.Y. This information was submitted to the user, who will use it in a presentation to the manufacturing firm to establish the desirability of locating the new plant in New York.

3. *A comparative study of small scale remotely sensed data for monitoring clearcutting in hardwood forests*

The N.Y.S. Adirondack Park Agency requested that the Program staff assess the utility of Landsat and other remotely sensed data for identifying and monitoring clearcutting in the Adirondack Park, in anticipation of extensive harvesting on private land within the Park following expiration of a moratorium on clearcutting. An area in the Allegheny National Forest, in northwestern Pennsylvania, was chosen for comprehensive study because of a lack of documented clearcuts in the Park. The two areas are similar in that they are covered by predominantly hardwood forests.

Manual interpretation techniques were used to analyze images acquired by high altitude aircraft, Skylab multispectral and Earth Terrain cameras, Landsat MSS, and Landsat-3 RBV. Landsat imagery also was analyzed using digital image analysis. The value of each type of remotely sensed data was judged by the ease and accuracy of clearcut identification, and by the amount of detail discernible, especially regarding revegetation.

A less comprehensive study was conducted in the Adirondack Park to confirm the transferability of findings from the Allegheny National Forest. Finally, a combined reconnaissance and detailed level methodology for identifying and monitoring clearcutting was recommended. (Appendix C).

4. *Assessment of potential industrial sites in Essex County, N.Y.*

In an attempt to improve its employment situation, Essex County, N.Y., is seeking to attract new industries. As part of its Economic Development Study, the County Planning Office must identify suitable industrial sites. The Program was requested to assist this effort.

Potential industrial sites were assessed using high and medium altitude aircraft photographs and supporting information on the 4,730 sq. km. (1,825 sq. mile) county. Factors evaluated include land availability, slope, site accessibility, soil drainage, other subsurface characteristics, and the expected physical as well as visual impacts on existing land use. Areas unavailable or unsuitable for development were eliminated first, and the remaining areas evaluated and the best sites identified. This information was submitted to the County Planning Office and will be used in site planning and attracting industry.

Program-Sponsored

As of November 30, 1980, the Cornell Remote Sensing Program staff was conducting four applied research projects and one assistance project under the NASA grant:

- ° applied research projects:
 1. Site Selection for Wind Mills
 2. Spectral Effects of Sulphur Dioxide
 3. Assessment of Scenic Views
 4. Studies of Vineyard Management and Yield Estimation
- ° assistance project:
 5. Remote Sensing Consultation Regarding the Love Canal Landfill

The objectives, cooperators, users, expected benefits and actions, and status of these projects are described, as follows:

1. *Site Selection for Wind Mills*

- cooperator/user: N.Y.S. Energy Office
- users: N.Y.S. Energy Office; citizens of New York
- benefits/actions: Selection of best sites for anemometers, and, if viable, wind mills
- expected completion date: 1st phase--February 1981

At the request of the N.Y.S. Energy Office, members of the Program staff are conducting a study to develop and test a site selection methodology for wind mills. Using topographic maps and remotely sensed data, and following accepted criteria, the staff has selected a number of sites for anemometers in western New York. Information about these sites was submitted to the Energy Office for inclusion in their final site selection. As planned, the methodology will be refined and tested in other areas.

2. *Spectral Effects of Sulphur Dioxide*

- cooperator: Boyce Thompson Plant Research Institute
- users: U.S. Environmental Protection Agency
- benefits/actions: Development of a procedure for monitoring SO₂ and its effects
- expected completion date: Feasibility study - February 1981

Researchers at the Boyce Thompson Plant Research Institute, at Cornell, are investigating the effects of sulphur dioxide on the yield of beans. During the summer of 1980, Program staff collected field spectroradiometric measurements and ground photographs on selected rows of beans, which had been exposed to varying concentrations of sulphur dioxide. These data are being analyzed and correlated with yield and gas concentration. Depending upon the results of the preliminary assessment, follow-up experiments might be conducted during 1981 to refine the selection of spectral bands for remote monitoring.

3. *Assessment of Scenic Views in Hamilton County, N.Y.*

-cooperator/user: Hamilton County Planning Department

-users: Hamilton County Planning Department, Town of Morehouse Planning Board

-benefits/actions: Selection of best sites for developing scenic view/roadside pull-offs, picnic areas

-expected completion date: June 1981

At the request of the Planning Department of Hamilton County, N.Y., the Program staff is assessing scenic views along Route 8 in the Town of Morehouse, N.Y. The county is situated within the Adirondack Park and is economically dependent on tourism. According to planners, improvements in scenic vistas along the highway would better identify the county with the Park, and thereby stimulate the local service industry. The objective of the project is to identify candidate roadside areas that the town could improve for scenic vistas, pull-offs, and picnic sites.

4. *Studies of Vineyard Management and Yield Estimation*

-cooperator/user: Taylor Wine Company; N.Y.S. Agricultural Experiment Station

-users: Taylor Wine Company & other vineyards; USDA Economics, Statistics & Cooperatives Service

benefits: Potentially, the capacity to improve and estimate vineyard yield with remotely sensed data

-expected completion date: September 1981

As a follow-up to previous vineyard-related investigations (7th, 9th, 14th, and 15th Semi-Annual Status Reports, Dec 1975, Dec 1976, June 1979, and June 1980), the Program staff is attempting to develop an algorithm for predicting vineyard yield on the basis of remotely sensed measurements. Photographic and multispectral scanner data acquired for the Program by NASA in 1977 are being re-evaluated;

a comprehensive series of field spectroradiometric studies were made in Cornell's experimental vineyard in Fredonia, N.Y. throughout the summer and early fall of 1980; and NASA/JSC flew one aircraft multispectral scanner mission over the Fredonia vineyard and Taylor Wine Company vineyards in Hammondsport, N.Y. in September 1980.

5. *Remote Sensing Consultations Regarding the Love Canal Landfill*

-cooperator:

N.Y.S. Dept. of Health

-users:

N.Y.S. Dept. of Health, N.Y.S. Dept. of Environmental Conservation, N.Y.S. Attorney General's Office, and U.S. Environmental Protection Agency

-expected completion date:

Present consultations--February 1981

As a follow-up to the Program's earlier analysis of the Love Canal landfill in Niagara Falls, N.Y. (13th Semi-Annual Status Report, Dec 1978), the Director of the Toxicology Laboratory of the N.Y.S. Department of Health has periodically requested additional remote sensing interpretations and support. These continuing consultations regarding the Love Canal landfill are proceeding under the NASA grant.

Spinoff Projects

During the past six months, the Program staff has been involved in two spinoff projects that arose directly from NASA-funded investigations. The first project is a remote sensing analysis of some 40 toxic waste landfills in the Niagara Falls area of New York. Partially supported by the N.Y.S. Department of Health, this work follows the Program's assessment of Love Canal (13th Semi-Annual Status Report, Dec 1978), as well as earlier leachate detection studies which were funded jointly by NASA and EPA.

Similarly, in an effort to extend the findings of a NASA-funded study of river flooding (14th Semi-Annual Status Report, June 1979), the Program sought and received a research grant to investigate flood modeling with Landsat. This 12-month study was funded by the Office of Water Research and Technology, U.S.D.I. and completed in October 1980.

The Program has begun another OWRT-funded study to develop a remote sensing methodology for improving lake sampling strategies. Begun in October 1980, this 12-month study is being conducted jointly with Cornell's Department of Natural Resources.

FUTURE PROJECTS

The Program staff is continually soliciting and receiving proposals for new remote sensing, applied research projects (Appendix

F). As described, criteria for project acceptance are that the project must be, in some way, unique; that project acceptance would not compete unduly with private companies or consultants; and that, if completed successfully, the project would produce tangible benefits or actions by defined users.

Among the projects that are planned for initiation during the next few weeks are:

1. With the *Boyce Thompson Plant Research Institute*--conduct greenhouse spectroradiometric studies to develop a remote sensing test for screening salt tolerance of tomatoes.
2. With the *Coastal Management Program, N.Y.S. Department of State*--develop a remote sensing methodology for inventorying coastal aesthetic resources that are located on, or visible from, public land.
3. With the *St. Regis Paper Company*--develop a remote sensing approach to locating desirable timber species in New York's Adirondack Mountains, for their wood procurement program.

PROGRAM STAFF

The Program staff is comprised of Ta Liang, principal investigator, Warren R. Philipson, co-investigator, John A. Stanturf, research associate, Thomas L. Erb, research specialist, Chain-Chin Yen, computer data analyst, and Pat Webster, secretary. Donald J. Belcher, Arthur J. McJair, and Ernest E. Hardy are general consultants to the Program, and for specific projects, assistance has been provided by many Cornell and non-Cornell personnel. Of special mention is the assistance of Michael J. Duggin of the College of Environmental Science and Forestry at Syracuse, N.Y. Students who have contributed significantly to the Program staff effort over the past six months include Lisa Balliett, Kent Craven, Karen Draves, William Hafker, Karen Jahn, Katsutoshi Kozai, Sandra Matulonis, Katherine Minden, David Smith and William Teng.

APPENDIX A

Fuelwood Availability for a Ten Megawatt
Power Plant in Tupper Lake, N.Y.,
Based on Remotely Sensed and Other Data

FUELWOOD AVAILABILITY FOR A
TEN MEGAWATT POWER PLANT IN
TUPPER LAKE, N.Y., BASED ON
REMOTELY SENSED AND OTHER DATA

Remote Sensing Program
Cornell University
Hollister Hall
Ithaca, New York 14853

September 1980

Preface

This study was initiated at the request of Mark Bagdon of the New York State Energy Office, and supported by NASA grant NGL 33-010-171.

Lisa K. Balliett, with the help of Karen Jahn did the remote sensing analysis and the land area estimation. John A. Stanturf is responsible for the fuelwood estimation. This study was directed by John A. Stanturf and Warren R. Philipson.

TABLE OF CONTENTS

	PAGE
I. Preface	1
II. Table of Contents	2
III. Introduction	3
IV. Summary and Conclusions	3
V. Methodology of Land Area Estimation	3
A. Methods and Materials	4
1. Sources of Information	4
2. Land Classification Process	4
3. Procedures for Identifying, Mapping, and Measuring Cover Types	6
B. Results and Discussion	7
1. Land Area Estimates	7
2. Data Limitations	8
3. Assumptions Made In the Classification Process	10
VI. Methodology of Fuelwood Estimation	10
A. Methods and Materials	10
1. Sources of Information	10
2. Gross Volume Estimates	11
3. Gross Fuelwood Estimates	12
B. Results and Discussion	14
1. Available Fuelwood Estimate	14
VII. References	19
VIII. Appendix. Fuelwood Demand Calculation	20

Introduction

Uncertainty in petroleum cost and supply has prompted renewed interest in alternative energy sources such as wood. The New York State Energy Office is considering development of a ten megawatt wood-fired power plant in the Adirondack Region. A primary consideration is the availability of sufficient woody material to fuel the plant. This study was undertaken to assess the potentially available woody material within an economic haul distance of Tupper Lake, New York.

In order to estimate potential fuelwood stocks, it was necessary to estimate the forest land area available, and the amount and type of woody material on the available land. A summary of these estimates and conclusions follow in the next section. More detailed descriptions of the methods used to derive these estimates are presented in subsequent sections. Explanation of the fuelwood demand calculations is appended.

Summary and Conclusions

Thirty-seven percent of the land within 30 km of Tupper Lake, totaling 1056² (260,940 acres), is forested and potentially available to supply wood. High altitude, color infrared aerial photographs and Landsat images showed the available land to be composed of 51% mixed stands, 39% deciduous stands, and 10% coniferous stands. Limiting consideration to land with slopes of 15% or less excluded 83,500 acres that would otherwise have been deemed available (but were not considered in the analysis).

The annual fuelwood demand for a ten megawatt (10 MW) plant was calculated using efficiency factors from the literature (Rich and Bauer 1975) and conservative high heat values (Tillman 1978). The fuelwood necessary to supply the plant was estimated to be 86,460 tons per year (green weight).

The amount of fuelwood potentially available was estimated several ways. The most conservative estimate assumes only "waste" wood is available--cull material and mortality. This was estimated to be 79,750 tons per year. Assuming sufficient additional top and stump residue from sawlog harvests will supply the balance, the most conservative estimate is that there is sufficient fuelwood within 30 km of Tupper Lake to supply a 10 MW plant without disrupting conventional timber markets. Less conservative estimates are that 1.35, 27, or 75 times the needed fuelwood could be supplied without relaxing the restriction on slopes or lengthening the hauling distance.

Methodology of Land Area Estimation

The land area potentially available for fuelwood production had to be estimated in order to determine whether or not the power plant could be supplied reliably. Since there is a distance beyond which wood fuel cannot be transported economically, a probable plant site had to be assumed and a reasonable hauling distance selected.

The study area was delineated as a circle of 30 km radius with the Village of Tupper Lake as the center. The amount and location of land potentially available was determined. Wetlands and water bodies were excluded and availability of the remaining area assessed according to ownership and harvestability. Fuelwood estimates were made using the estimates for land area in three forest types interpreted from aerial photographs and satellite images, and mensurational data in the 1970 Forest Survey of New York (Ferguson and Mayer, 1970) and other studies.

Methods and Materials

Sources of Information

The remotely sensed and supplemental data examined to determine non-forested areas, wetlands and water bodies, slope, forest cover types, and property ownership boundaries included several dates of high altitude color infrared aerial photography, two Landsat color composite images, two land use maps of the Adirondack State Park, maps of industry owned land, and USGS topographic maps. These data sources are summarized in Table 1.

Land Classification Process

A land classification was established to exclude land where whole-tree harvesting is difficult because of physical or legal limitations. Land was excluded unconditionally if it was State-owned, wetland, or non-forested. Land with harvestability limitations due to slopes greater than 15% were also excluded. Industry owned land was included but boundaries were noted in order that these lands could be assessed separately. All other land was classified as potentially available. Forest cover types were delineated as being dominantly coniferous, deciduous, or mixed. Forest cover types were mapped on all potentially available land, including that in industry ownership.

Excluded land had absolute limitations on harvesting. The majority of the land in this category was in the Adirondack Forest Preserve. Wetlands throughout the study area were excluded because of the likelihood of adverse environmental impact if disturbed. Furthermore, wetlands often lack woody material.

Non-forested land was excluded; however, some of these areas, for example recent clearcuts, might be considered available at some time in the future.

Land with some limitations included land with slopes greater than 15%. Assuming that at least in some areas, woody material will be chipped on site and trucked to the plant, a slope limitation of 15% was chosen to meet the requirements of mechanical chippers and to avoid unstable slopes (Bogucki, 1977). This slope limit is conservative. Steeper lands can certainly be harvested without undue environmental impact, however, at higher economic costs.

Several of the large companies owning land in the area stated their willingness to sell varying amounts of waste wood, forest residues and unmerchantable timber. Thus, industry owned land was treated

Table 1. Information sources used in compiling maps and estimating available land area.

Date/Type/Source	Scale	Forest		Wetland	Water Bodies	Slope	Ownership	
		Cover	Non-Forest				State	Private
25 June 1979/ Color Infrared Airphoto /NASA	1:118,000	X	X	X				
20 May 1974/ Color Infrared Airphoto/NASA	1:116,000	X	X	X				
30 April 1973/ Color Infrared Airphoto / NASA	1:116,000	X	X	X				
8 July 1973/ Landsat Color 1 Composite/NASA	1:1,000,000	X						
8 January 1973/ Landsat 2 Color Composite/NASA	1:1,000,000	X						
April 1979/ Adirondack Park/ Adirondack Park Agency	1:175,000							X
September 1974/ Adirondack Park State Land Master Plan Map/ Adirondack Park Agency	1:268,000							X
1975-1976/ International Paper Company Forest Survey Maps/International Paper Co.	1:65,500							X
1953-1955/ 15 Minute Topographic Maps / US Geological Survey ³	1:62,500	X	X	X	X	X		
1966-1970/ 7½ Minute Topographic Maps / US Geological Survey ⁴	1:24,000	X	X	X	X	X		

1 Scene # E1350-15174

2 Scene # E1169-15121

³ Blue Mountain, Long Lake, Newcomb, Raquette Lake, St. Regis, Santoni, Saranac Lake, Tupper Lake.

⁴ Augerhole Falls, Brother Ponds, Carey Falls Reservoir, Childwold, Cranberry Lake, Mount Matumbia, Stark, Wolf Mountain (optically reduced to a scale of 1:62,500)

as available but location was noted. The only industry owned land within the study area belongs to the International Paper Company and the St. Regis Paper Company. The boundaries of the International Paper Company land are shown on Map Two.

No limitations were put on the remaining land. A study done by Canham (1973) showed that owners' attitudes change, and have little long term effect on whether the property will be harvested because ownership often changes at least once during the life of the stand.

The land not excluded absolutely or conditionally was used as the forested area available to supply fuelwood. This land base was then stratified into three cover type classes by aerial photographic interpretation. The forest type classes are coniferous, deciduous, and mixed. The estimates of land area in each type were used along with the Forest Survey data to estimate woody material.

Procedures for Identifying, Mapping, and Measuring Cover Types

A base map was constructed from USGS topographic maps at a scale of 1:62,500. Acetate sheets showing the different land classifications were placed over the base map. A circle of 30 km radius was drawn with the Village of Tupper Lake as the center. The 30 km radius represents a reasonable hauling distance. The total area within the circle is 282,600 ha (698,300 acres). Parts of St. Lawrence, Essex, Franklin and Hamilton counties are included.

The topographic maps were used to measure slope in order to exclude lands greater than 15%. All property ownership maps were projected to the scale of the base map using an opaque projector.

Interpretation was begun by locating areas in each land cover type (e.g., wetlands) on the topographic maps and by identifying their characteristics on the color IR aerial photographs. Once land cover types could be identified consistently using the color IR aerial photos viewed stereoscopically, they were mapped for the study area. Acetate overlays were made by optically superimposing each photographic frame onto the base map using a Zoom Transfer Scope. In this manner, relevant information from the topographic maps could be updated.

Few changes were found in wetlands as they appeared on the topographic maps; however, several new non-forested areas were located. Some of these were recent clearcuts (Hafker, 1980). Others were expanding residential areas.

The high altitude color IR film was studied on a light table to identify forest cover types. The cover type categories--coniferous, deciduous, and mixed forests--were based on uniform units that could be differentiated on the photographs and were more general than the cover types used by foresters. The relatively small scale of the photos precluded finer delineation of the cover types.

Landsat color composite transparencies were used to confirm identification of cover types. Winter images were especially helpful in identifying conifers. After all available land was assigned to forest cover type classes, areas were measured using a one hectare grid.

Results and Discussion

Three map overlays were produced. Map One shows the three forest cover types on potentially available land. Map Two shows the land conditionally excluded due to slopes greater than 15%. Forest industry owned land boundaries are also shown on this map. Map Three shows excluded land--wetlands, water bodies, non-forested land, and Forest Preserve land. These overlays can be used together or separately.

Land Area Estimates

Thirty-seven percent of the land within 30 km of Tupper Lake, total-1056 km² is forested land potentially available to supply wood to a power plant. Analysis of color IR photography and Landsat images shows this to be composed of 51% mixed, 39% deciduous, and 10% coniferous forests (Table 2).

Table 2. Estimates of potentially available land
in three cover types
in the four counties of the study area.

County	Coniferous	Deciduous	Mixed	Total	% of Total
St. Lawrence	2,710 ha. 6,690 acres	14,380 ha. 35,550 acres	27,210 ha. 59,830 acres	44,300 ha. 102,070 acres	42
Hamilton	4,880 ha. 12,060 acres	9,370 ha. 23,140 acres	11,260 ha. 27,810 acres	25,510 ha. 63,010 acres	24
Franklin	2,940 ha. 7,260 acres	16,540 ha. 40,870 acres	15,370 ha. 37,990 acres	34,850 ha. 86,120 acres	33
Essex	10 ha. 30 acres	760 ha. 1,870 acres	170 ha. 420 acres	940 ha. 2,320 acres	1
Total	10,540 ha. 26,040 acres	41,050 ha. 101,430 acres	54,010 ha. 126,050 acres	105,600 ha. 253,520 acres	
% of Total	10	39	51		

Source: Interpreted from high altitude color infrared aerial photographs.

Complete data on the location of industry owned land was not available, however International Paper Company lands within the study area are shown on Map Two. The total amount of International Paper Company land in the study area is 23,540 ha. The breakdown of this land into the cover types in each county is shown in Table 3.

Table 3. Land area owned by International Paper Co.
included in the potentially available land base.

County	Coniferous	Deciduous	Mixed	Total	% of Total ¹
St. Lawrence	840 ha. 2,090 acres	4,040 ha. 9,970 acres	7,150 ha. 17,660 acres	12,030 ha. 29,720 acres	27
Hamilton	840 ha. 2,070 acres	2,790 ha. 6,890 acres	3,290 ha. 8,140 acres	6,920 ha. 17,100 acres	27
Franklin	540 ha. 1,330 acres	1,740 ha. 4,300 acres	2,310 ha. 5,720 acres	4,590 ha. 11,350 acres	13
Essex	0	0	0	0	
Total	2,220 ha. 5,490 acres	8,570 ha. 21,160 acres	12,750 ha. 31,520 acres	23,540 ha. 58,170 acres	22

¹ The values for total area used to calculate percentages are from the appropriate column in Table 2.

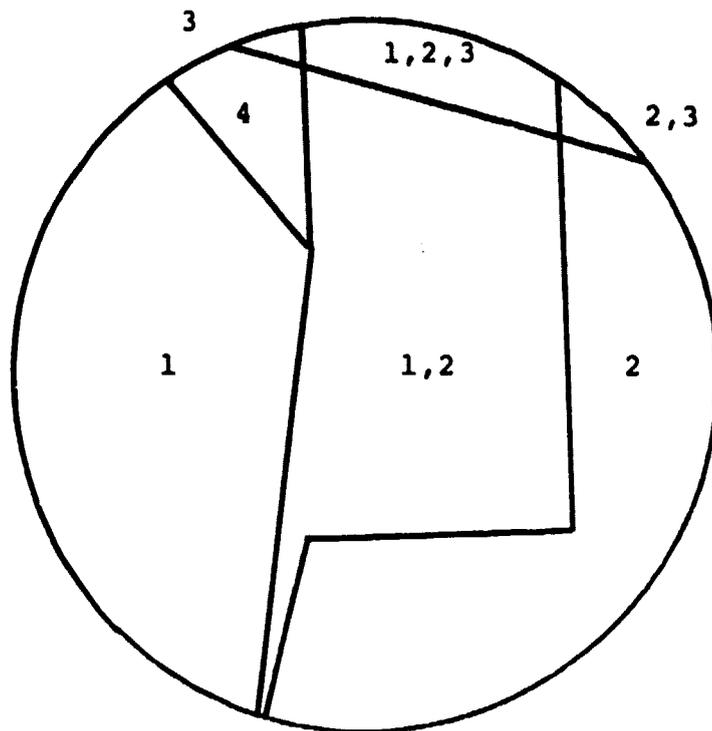
Most of the potentially available land is within St. Lawrence, Franklin, and Hamilton counties. Less than 1,000 ha lies in Essex County. The greatest amount of deciduous forest is in Franklin County (16,540 ha) while Hamilton County has the most coniferous forest (14,380 ha). The amount of land excluded by the 15% slope limitation is shown in Table 4 and is 34,220 ha. The land in the study area which was excluded because slopes were greater than 15% was 32% as much as the potentially available land.

Table 4. Land area excluded because slopes exceeded 15%.

St. Lawrence	Hamilton	Franklin	Essex	Total
9,180 ha. 22,700 acres	8,780 ha. 21,680 acres	15,170 ha. 37,490 acres	1,090 ha. 2,690 acres	34,220 ha. 84,560 acres

Data Limitations

Although the entire study area (except for a small piece in the north-west corner) was covered by high altitude color IR photography, no single flight covered more than 50% of the study area (Figure 1). This caused some inconsistency in classification of land cover types. Coverage overlapped enough, though, that differences in the images (due to season of coverage or film development) could be overcome.



LEGEND

- 1 = Color Infrared (High Altitude Aircraft) April 1973
- 2 = Color Infrared (High Altitude Aircraft) June 1979
- 3 = Color Infrared (High Altitude Aircraft) May 1974
- 4 = Landsat July 1973

Figure 1. Extent of remote sensing coverage of the study area (30 KM radius from the Village of Tupper Lake).

Another inconsistency which could not be adjusted for was the difference in date of coverage. Fifty percent of the area was classified using June, 1979 photographs, whereas the other half was done using older (April 1973 and May 1974) photographs. Consequently, one half of the final product is up-to-date while the other half of the information is six to seven years old. This is only critical where stands have been clearcut. The areas classified using the various dates of photography are shown schematically in Figure 1.

The ease with which conifers and deciduous trees could be differentiated varied with the season of photography and no doubt affected the accuracy of classification. The older (1973 and 1974) photography was taken in the spring when deciduous trees were bare and conifers could be identified easily. On the other hand, it was easier to detect the presence of deciduous trees in the leaf-on condition on the June 1979 photography.

Landsat color composite images were studied to aid identification of forest cover types. Conifers were especially noticeable on the January 1973 image. Landsat images were the only source available in a small portion of the study area (Figure 1).

Assumption Made in the Classification Process

The assumptions made in classifying land in order to exclude non-available land should result in a conservative estimate of the land base. The exclusion of land greater than 15% slope is more restrictive than that put on conventional sawtimber harvest. This restriction was used since there is less experience in the Adirondacks with the more mechanized harvesting systems likely to be used for fuelwood harvests. The ecological effects of more complete removal of tops and cull trees are incompletely known, so a cautious approach seemed justified.

Methodology of Fuelwood Estimation

The land area estimates of forest cover types do not provide estimates of the fuelwood available. Applying average per acre values to the land base for growing stock volume and annual removals from the Forest Survey (Ferguson and Mayer 1970), and data from studies of gross growth, percent cull, mortality (Ferree and Hagar 1956) and weight of woods in tops of trees (Monteith 1979) allows estimates to be made of present growing stock volume and annual growth. Assuming average BTU and moisture content, the ability of the available timber resources to supply a wood-fired power plant under different management schemes can be assessed.

Methods and Materials

Sources of Information

The 1970 Forest Survey of New York (Ferguson and Mayer, 1970) was the primary source of mensurational data available for the study area.

Average data for each county were calculated and used. The figure for annual removals from the Northern Region was used.

Estimates of gross annual growth, mortality, and cull percent were obtained from a study of timber growth rates of natural stands in New York (Feree and Hagar, 1956). An estimate of the weight of branch material from tree tops was obtained from work by Monteith (1979).

An annual fuelwood demand of 86,460 green tons for a 10 MW power plant was estimated according to the method used in a feasibility study for a wood-fired power plant in Vermont (Rich and Bauer, 1975).

Gross Volume Estimates

Definitions of growing stock volume vary between studies. In this section an estimate of the growing stock volume in the study areas, as of 1968, is made using data from the Forest Survey. Average volume per acre in each forest cover type (as defined in the Forest Survey) was calculated by dividing total volume in a cover type in a county by the acreage in a cover type in that county. Thus, growing stock volumes per acre were calculated for pine, spruce-fir, other softwoods, oak, elm-ash-red maple, maple-beech-birch and aspen-birch cover types in each county.

The volumes per acre, given in Table 5, appear reasonable in that they are the same as volumes for poletimber stands (Feree and Hagar, 1956). Actual distributions of stand size classes are given in Table 6. More than half the area in Essex and Hamilton counties is in sawtimber stands, and about half the area in St. Lawrence and Franklin counties is in seedling and sapling stands. Therefore, the use of average volume per acre probably underestimates volume in Essex and Hamilton counties, and overestimates volume in the other two counties. Since the actual distribution of stand size classes in our study area was unknown, the significance of the bias cannot be assessed.

Table 5. Average volumes per acre of Forest Survey cover types ($\times 10^3$ cubic feet).

County	Pine	Spruce- Fir	Other Softwoods	Oak	Elm-Ash- Red Maple	Maple-Beech- Birch	Aspen- Birch
St. Lawrence	1.04	0.78	1.12	0.79	0.67	0.75	0.32
Hamilton	1.19	1.15	1.55	0.92	0.73	1.00	1.19
Franklin	1.02	0.81	1.2	0.81	0.71	0.83	0.36
Essex	1.21	1.18	1.56	0.88	0.83	1.02	1.13

Source: Calculated from Tables 82 and 86 in Ferguson and Mayer (1970).

Table 6. Percentages of land area in the study area counties in three stand size classes.

County	Sawtimber	Poletimber	Sapling/ Seedling
St. Lawrence	26	19	46
Hamilton	57	15	27
Franklin	29	20	43
Essex	54	17	28

Source: Table 81 in Ferguson and Mayer (1970).

Note: Figures do total to 100% because some land in category of "other" is not shown.

A volume per acre figure was obtained for three classes of forest cover types (i.e., coniferous, deciduous, and mixed) by combining the values for the Forest Survey types. The coniferous class included pine, spruce-fir, and other softwoods, and the deciduous class included oak, elm-ash-red maple, maple-beech-birch, and aspen-birch. Volume per acre for the mixed class was taken as the average of the values derived for the coniferous and deciduous classes. Values used were weighted averages of the values from the appropriate Forest Survey types. Weighting factors were derived on the basis of the acreage in each Forest Survey type in each county. Table 7 shows the weighted volume per acre, the growing stock volume in each county, and the weight of the growing stock.

Gross Fuelwood Estimates

Gross volume in 1980 can be estimated using the values for cull percentage, mortality, and gross growth given by Ferree and Hagar (1956) and the annual removal figure for the Northern Region from the Forest Survey. This represents the volume of all trees at or above the minimum diameter at breast height (dbh) before deductions are made for cull. Since the 1968 gross volume estimates made from Forest Survey data do not include cull, substantially more material might be available.

The 1980 gross volume was estimated from the 1968 volume, using Method 2 of Ferree and Hagar (1956) for Growth Region B. They gave tabled values of total gross growth (including cull) per acre per year by growing stock volume classes. They defined gross growth as gross accretion (the increase in timber volume due to the growth of trees at or above a minimum dbh at the beginning of the growth period, expressed as an average annual rate per acre over 10 years), plus gross ingrowth (gross volume of small trees attaining minimum dbh during the growth period, expressed as an average annual rate over a 10 year period). For each year, gross growth was read from the table and added to the beginning volume (i.e., volume from the previous year).

Table 7. Weighted Volumes per acre, 1968 growing stock volume, and 1968 growing stock weight, on available land.

County	Weighted Volume per Acre $\times 10^{-2} \text{ ft}^3$			1968 Growing Stock Volume ft^3			1968 Growing Stock Weight Tons		
	Coniferous	Deciduous	Mixed	Coniferous	Deciduous	Mixed	Coniferous	Deciduous	Mixed
St. Lawrence	0.909	0.646	0.778	6,083,000	22,963,000	46,549,000	82,000	367,400	686,600
Hamilton	1.159	0.983	1.071	13,976,000	22,751,000	29,787,000	189,000	364,000	439,400
Franklin	0.939	0.713	0.826	6,819,000	28,137,000	31,376,000	92,000	466,200	462,800
Essex	1.208	0.858	1.033	30,000	1,603,000	432,000	400	25,600	6,400
Total				26,909,000	76,454,000	108,144,000	363,400	1,223,200	1,595,200

Source: Estimated from data in Ferguson and Mayer (1970). See text for explanation of estimation procedure. Conversion from volume to weight used values from Tillman (1978): 1 ft^3 coniferous = 0.0135 tons; deciduous = 0.016; mixed = 0.0148.

Annual mortality is also provided by Ferree and Hagar (1956). This was subtracted from the gross volume. An annualized removal estimate for the Northern Region, which included the study area, was taken from the Forest Survey and subtracted from the gross volume. The result is the gross volume at the end of the period (one year), which is also the starting volume of the next period. This procedure was repeated for each year between 1968 and 1980, for each cover type in each county. The 1980 Gross Volumes are given in Table 8. The weight of woody material was calculated in order to convert to energy values. Average values for conifers (27 lb./ft³) and deciduous trees (32 lb./ft³) were obtained from the literature and the average of these (29.5 lb./ft³) was used for mixed forests. These values are for green wood.

Table 8. 1980 Gross Volume estimates in cubic feet. Projection from 1968 Gross Volume, less annual mortality and removals between 1968-1980. Includes cull material but not tops and branches.

County	Coniferous	Deciduous	Mixed	Total
St. Lawrence	10,426,000	35,546,000	76,644,000	122,616,000
Hamilton	23,117,000	34,114,000	47,303,000	104,534,000
Franklin	11,583,000	44,830,000	51,128,000	107,541,000
Essex	50,000	2,415,000	693,000	3,158,000
Total	45,176,000	116,905,000	175,768,000	337,849,000

The 1980 Fuelwood Weights in Table 9 include the weight of branches. An estimate of the weight of the bole plus tops and branches (to a 3 inch diameter) was obtained from Monteith (1979). He gave values for conifers and deciduous trees by diameter classes. An average value for each cover type in each county was derived by averaging his diameter class values into sawtimber and poletimber averages, then weighting these by the volume of growing stock in each stand size class (sawtimber, poletimber, and seedling/sapling) in a county.

Results and Discussion

Available Fuelwood Estimate

The weight of wood on available land in 1980 is given in Table 9. The upper value in each category is without a correction for tops, while the lower value includes it. These values are conservative as they do not include weight of stumps (which can be considerable for large trees), nor do they include material such as non-commercial species and brush. To put these figures into relief, assume that the entire weight is available for harvest and could be used for fuel.

Assuming an average value for BTU/Ton green wood of 10.5 million (Tillman, 1978), there would be 6.94×10^{15} BTU available. Using an annual fuelwood demand of 86,460 tons (see Appendix), the wood in 1980 could supply a 10 MW power plant for more than 75 years. It is unreasonable to assume this wood is available and should be diverted to supplying a power plant, nor is it necessary to consider such an extreme situation.

Table 9. 1980 Weight of wood volume in tons, using 1980 Gross Volume estimate from Table 7 (upper value in each category), corrected for weight of tops (lower value). Volume to weight conversions from Tillman (1978).

County	Coniferous	Deciduous	Mixed	Total
St. Lawrence	140,800	568,000	1,130,500	1,840,100
	192,700	720,600	1,490,000	2,403,300
Hamilton	312,100	545,800	697,700	1,555,600
	414,100	695,900	907,700	2,017,700
Franklin	156,400	717,300	754,100	1,627,800
	215,000	913,100	998,500	2,126,600
Essex	700	38,600	10,200	49,500
	900	49,200	13,300	63,400
Total	610,000	1,870,500	2,592,500	5,073,000
	822,700	2,378,800	3,409,500	6,611,000
Top Weight	212,700	508,300	817,000	1,538,000

Assuming all the material in the tops, the present cull, and mortality (from now on) is available, then 2,367,930 tons are available (Table 10). This is enough to supply the plant for 27 years. This assumes that harvest removals for sawtimber and roundwood remain at 1968 levels. An additional 50,000 tons should be available in subsequent years due to continued mortality. This estimate unrealistically assumes that top material can be harvested separately from the bole.

In order to determine whether sufficient material could be available indefinitely from annual growth, two approaches were taken. Estimates of annual growth after historic removals are given in Table 11. Applying these to the available land area yields an estimate of 116,660 tons available yearly, 35% more than necessary. The annual growth rates were estimated from the increase in gross volume between 1968 and 1980.

Table 10. Fuelwood available annually from cull, mortality, and tops, in tons.

	Weight Mortality	Weight Cull	Weight Tops	Total
Coniferous	4,750	30,500	212,900	248,150
Deciduous	20,290	411,500	508,400	940,190
Mixed	25,590	337,000	817,000	1,179,590
Total	50,630	779,000	1,538,300	2,367,930

Source: Values for available land (Table 2) used to estimate annual mortality, based on average annual mortality per acre of 135, 125, and 130 cubic feet for coniferous, deciduous, and mixed, respectively. Gross 1980 volume from Table 8 was used to estimate cull using 5, 22, and 13 percent cull on a volume basis for coniferous, deciduous, and mixed, respectively. Weight of tops was obtained from Table 9.

Table 11. Weight of annual growth, tons per year. Growth includes cull and mortality after deduction is made for annual removals. Net growth rates estimated from increase between 1968 and 1980.

County	Net Growth Rates ft ³ /acre/year			Weight of Net Growth, tons/year			Total
	Coniferous	Deciduous	Mixed	Coniferous	Deciduous	Mixed	
St. Lawrence	50	18	34	4,520	10,240	30,000	44,760
Hamilton	59	23	40	9,600	8,520	16,410	34,530
Franklin	51	19	34	5,000	12,420	19,050	36,470
Essex	62	21	40	20	630	250	900
Total				19,140	31,810	65,710	116,660

The second approach used regional net growing stock growth rates from the Forest Survey, corrected for cull and top weight (Table 12). Net growth here means accretion plus ingrowth, minus mortality and cull. An estimated 97,250 tons would be available annually, or just enough to supply the plant.

Table 12. Weight of annual growth, tons per year. Weight estimates include corrections for culls and tops. Growth Rates were estimated from growth in the Northern Region.

	Net Growth ft ³ /acre/year	Weight of Net Growth tons/year
Coniferous	25	12,460
Deciduous	12	31,410
Mixed	18	53,380
Total		97,250

Source: Net growth rates were estimated from the rates for the Northern Region in the Forest Survey (Ferguson and Mayer, 1970).

The estimated growth from the first method is higher than the second method, probably due to a combination of factors. The annual growth rates were for the Northern Region which included the Eastern Adirondacks. There was a decrease in growing stock volume in that unit between the 1950 and 1970 surveys (Ferguson and Mayer, 1970) that probably lowered the regional rate compared to the St. Lawrence-Northern Adirondack and Western Adirondack units (where the study area is located). Additionally, the amount of cull is probably underestimated in the second procedure by using the estimate of cull from Ferree and Hagar (1956) on the Forest Survey data.

The estimated annual available fuelwood weight, using the Forest Survey regional growth rates, is the sum of (cull available from net growth) + (annual mortality) + (weight of tops from cull and mortality). This estimate is 79,750 tons per year (Table 13). To this amount should be added top and stump residue from sawlog harvests, and a portion of the accumulated cull plus other thinnings. Thus, even the most conservative estimation procedure shows that there should be sufficient fuelwood available within 30 km of Tupper Lake without disrupting conventional wood markets.

Table 13. Estimated weight of fuelwood available from annual growth.

	Cull	Mortality	Tops	Total
Coniferous	440	4,750	1,810	7,000
Deciduous	5,260	20,290	7,010	32,560
Mixed	5,320	25,600	9,270	40,190
Total	11,020	50,640	18,090	79,750

Source: Annual growth from Table 12 was used to estimate cull and top weights; mortality weight is from Table 10.

References

- Bogucki, D.J. 1977. Debris slide hazards in the Adirondack Province of New York State. *Environmental Geology* 1:317-328.
- Canham, H.O. 1973. Forest ownership and timber supply. SUNY College Environmental Science and Forestry Report. Syracuse, New York.
- Ferguson, R.H. and C.E. Mayer. 1970. The timber resources of New York. USDA Forest Service Resource Bulletin NE-20. Northeastern Forest Experiment Station, Upper Darby, Pennsylvania.
- Ferree, M.J. and R.K. Hagar. 1956. Timber growth rates for natural stands in New York State. SUNY College of Forestry Technical Publication 78. Syracuse, New York
- Hafker, William R. 1980. Personal communication.
- Monteith, D.B. 1979. Whole tree weight tables for New York. Applied Forestry Research Institute Research Report No. 40. SUNY College Environmental Science and Forestry, Syracuse, New York.
- Rich, J.P. and P.H. Bauer. 1975. The feasibility of generating electricity in the State of Vermont using wood as a fuel: A study. Report to State of Vermont, Agency of Environmental Conservation, Department of Forests and Parks by J.P.R. Associates, Inc., Stowe, Vermont.
- Tillman, D.A. 1978. Wood as an energy resource. Academic Press, New York.

Appendix. Calculation of annual fuelwood demand, 10 magawatt power plant

The method is from Rich and Bauer (1975), but the more conservative high heating value of 5250 BTU/lb. green wood (8000 BTU/lb. drywood) from Tillman (1978) is used. Fuelwood demand is given by:

$$X \text{ tons} = 10 \text{ MW} \times \frac{10^3 \text{ KW}}{\text{MW}} \times \frac{3413 \text{ BTU}}{\text{KWH}} \times \frac{8760 \text{ hours}}{\text{year}} \\ \times \frac{\text{lbs.}}{5250 \text{ BTU}} \times \frac{\text{ton}}{2 \times 10^3 \text{ lbs.}} \times (0.75) \times \left(\frac{1}{0.247}\right)$$

where X = annual fuelwood demand in tons

.75 = capacity factor

.247 = overall plant efficiency

MW = megawatts

KW = kilowatts

KWHR = kilowatt hours

BTU = British Thermal Units

lb = pounds

N81-25456

APPENDIX B

Inventory of Coniferous Forests
Near Bath, N.Y.



Cornell University

REMOTE SENSING PROGRAM
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
HOLLISTER HALL
ITHACA, NEW YORK 14853
(607) 256-4330, 256-5074

November 14, 1980

Jack Kahabka
Conservation Consultant
155 East Morris Street
Bath, N.Y. 14810

Dear Jack:

At your request, we conducted a project to document the amount of conifer forests within 50 miles of Bath, N.Y., using existing remotely sensed data. This work, supported by NASA Grant NGL 33-101-171, is now complete. This letter serves as our project report.

Problem and Approach to Solution

A particleboard manufacturing firm is considering constructing a new plant in the Southern Tier near Bath, N.Y. A primary factor in assessing the feasibility of the plant is the supply of conifers and low-density hardwoods. Available information on forest resources is aggregated (the smallest unit for which data are reported is a county) and dated (New York--1970, Pennsylvania--1965).

At your request, staff of Cornell's Remote Sensing Program estimated land area supporting conifers by interpreting high altitude, color infrared aerial photographs and Landsat satellite images. The delineation of low-density hardwoods was not attempted as this poses a more difficult problem, requiring larger-scale data, more ground-truth, or both, than were available.

Materials and Methods

A study area was defined as a circle with a radius of 50 miles around Bath, N.Y. Several dates of NASA high altitude, color infrared aerial photographs (scale approximately 1:120,000) were available for the northern half of the study area, in the Finger Lakes region. Photographs taken on 18 August 1978 (NASA/JSC Mission 387) were used because they were the most recent. Interpretation was done using a zoom stereoscope, and areas of conifers were delineated on acetate sheets. A grid with cell size of one square millimeter was used to tally the units. Scale was determined for each photograph and units converted to acres.

High altitude photographs were available for only a small portion of the southern half of the study area. Several dates of Landsat images, however, were on file. A winter and a summer scene were examined, and these not only covered the area of interest but

overlapped the area imaged by the high altitude photographs. This was beneficial in that spectral characteristics of stands mapped as conifers on the high altitude photographs could be examined on the Landsat images, thereby training the interpreter to recognize conifers.

The Landsat bands 5,6, and 7, corresponding roughly with the visible red and two bands in the near infrared portions of the electromagnetic spectrum, were used. Photographically enlarged positive transparencies of bands 5,6, and 7 were placed in a color additive viewer and registered with each other to provide a composite image at a scale of approximately 1:184,500. The color additive viewer allows blue, green, red, and white light to be shown through each of the transparencies separately by the use of filters. The resulting false-color image displayed on a viewing screen can be interpreted in a fashion similar to the interpretation of the high altitude photographs. Choice of colors, however, is arbitrary. The stands in the area with photographic coverage were examined using various filter combinations until conifers could be delineated confidently. The best discrimination was obtained with the winter scene (25 October 1973, ID# 1459-15221). A green filter was used on band 5, blue on band 6, and red on band 7. Conifers appeared as dark, reddish-purple.

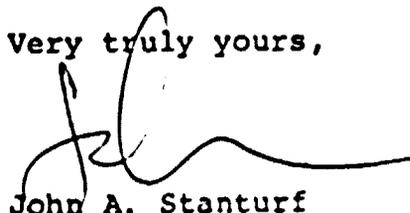
After the conifer stands in the southern portion of the study area were delineated, acreage was estimated using a grid as described above. Luther Auchmoody, Research Forester with the USDA Forest Service Forestry Sciences Lab in Warren, Pa., was consulted regarding the interpretation of conifer stands in northern Pennsylvania. He stated that conifers often are found along drainage ways, with few pure stands likely unless they are plantations. This supported the interpretation of stands in the northern Pennsylvania part of the study area as predominantly, but by no means solely, conifers.

Results

The total area in conifer stands within 50 miles of Bath, N.Y., was approximately 176,000 acres. Thirty-eight percent, or 66,000 acres, are located in Pennsylvania.

If I can be of help in answering questions about our methods or clarifying any points, please do not hesitate to contact me.

Very truly yours,


John A. Stanturf
Research Associate

ORIGINAL PAGE IS
OF POOR QUALITY

cc: Ta Liang
Warren Philipson

N81-25457

APPENDIX C

A Comparative Study of Small Scale
Remotely Sensed Data for Monitoring
Clearcutting in Hardwood Forests

Original photography may be purchased from
EROS Data Center

Sioux Falls, SD 57198

SMALL SCALE REMOTELY SENSED DATA FOR
MONITORING CLEARCUTTING IN PENNSYLVANIA HARDWOOD FORESTS

A Thesis

Presented to the Faculty of the Graduate School
of Cornell University
in Partial Fulfillment for the Degree of
Master of Science

by

William Robert Hafker

August 1980

ABSTRACT

The value of various types of high altitude aircraft and satellite remotely sensed data for monitoring clearcutting in predominantly hardwood forests was assessed. Manual photo-interpretation techniques were used to analyze images acquired by high altitude aircraft, the Skylab Multispectral and Earth Terrain Camera (ETC), the Landsat Multispectral Scanner (MSS) and the Landsat-3 Return Beam Vidicon Camera. Landsat MSS imagery was also analyzed using a color-additive viewer, and by digital image analysis. The value of each type of remotely sensed data was judged by the ease and accuracy of clearcut identification, and by the amount of detail discernible, especially regarding revegetation.

Results of the comprehensive study of a site in the Allegheny National Forest, Pennsylvania, indicate that high altitude aerial photography, especially color infrared photography at scales of 1:130,000 and 1:430,000, acquired during the growing season, is well suited for identifying clearcuts and assessing their revegetation. Although photographs acquired with Skylab's ETC also yielded good results, only incomplete inventories of clearcuts could be made using Landsat imagery.

A less comprehensive assessment of the utility of these small scale data sources for clearcut monitoring in the Adirondack region of New York State yielded similar results for the aircraft and satellite photography, but even less satisfactory results with Landsat imagery.

Based on the findings of this study, procedures were outlined for the development of methodologies for clearcut monitoring using small scale remotely sensed data.

BIOGRAPHICAL SKETCH

William Robert Hafker was born in Flushing, New York, on June 23, 1957. He received his primary education at Redeemer Lutheran Elementary School, and graduated as valedictorian of Martin Luther High School in June 1975. In September 1975 he entered Cornell University's School of Agriculture and Life Sciences, and majored in natural resources with a concentration in environmental evaluation and assessment. He was awarded his Bachelor of Science degree with honor and distinction in January 1979. Beginning that same month he entered a graduate program in Cornell University's School of Civil and Environmental Engineering, majoring in Aerial Photographic Interpretation and Remote Sensing, and minoring in Geomorphology. While completing his Master of Science degree he worked as a research assistant for the Cornell Remote Sensing Program, studying the use of satellite imagery for flood estimation, and developing a methodology for beach identification and characterization in New York State.

During his time at Cornell he received the Bausch & Lomb Award for the best paper on photogrammetry by an undergraduate, the Central New York Region of the American Society of Photogrammetry's Student of the Year Award, and the Legislative Council on Photogrammetry Scholarship. He is a member of the American Society of Photogrammetry and The Remote Sensing Society (United Kingdom).

ACKNOWLEDGEMENTS

The support of several people and organizations during various phases of this study has been of great value, and is deserving of thanks.

My thesis committee, Profs. Ta Liang, Arthur Bloom, and Warren Philipson, are especially to be thanked for their help in conducting and reporting this study. I also thank Prof. Liang for increasing my ability to analyze and understand the physical environment through airphoto interpretation; Prof. Bloom for building my knowledge of geomorphology; and Warren for teaching me, both formally and informally, the principles of remote sensing, for helping me improve my research and writing skills, and for being a readily available and knowledgeable friend.

The assistance and information provided by Harold Schopper and John Serfass, of the Allegheny National Forest, Sheffield Ranger District, was invaluable. Also to be thanked for providing ground data are Richard Sage of the Archer and Anna Huntington Wildlife Forest Station, and Robert Meyer of Sher-Don Associates Inc.

Appreciation is extended to Dr. Ernest Hardy and Jennie Barnaba of the Resource Information Laboratory for allowing me the use of their facilities, and especially to Steve Smith for coordinating my work at the Lab.

Additionally, I thank the members of the Cornell Remote Sensing Program for the support and help that they offered during my time there. I especially thank Tom Erb for his useful advice, Erik Bongue and Bill

Altman for their photographic assistance, to Chain-Chin Yen for running the digital Landsat analysis, and to Elaine Aderhold, Jan Berger, Jennifer Ortiz, Bill Teng, and Tom Wozny for the friendship, insights, and good times that we shared.

John Banta and Ray Curran are to be thanked for planting the seed for this study in the author's mind.

Support for this investigation was provided by Grant NGL 33-010-171 from the National Aeronautics and Space Administration (NASA).

TABLE OF CONTENTS

	PAGE
1. <u>INTRODUCTION</u>	1
1.1 Statement of Problem.....	1
1.2 Objectives.....	3
2. <u>LITERATURE REVIEW</u>	4
2.1 Forest Harvesting.....	4
2.1.1 Forest Harvesting Techniques.....	4
2.1.2 Concerns Regarding Clearcutting.....	6
2.2 Remote Sensing Parameters.....	8
2.2.1 Spectral Sensitivity.....	9
2.2.2 Image Scale and Resolution.....	12
2.2.3 Season.....	13
2.3 Remote Sensing Systems.....	15
2.3.1 Aerial Photography.....	15
2.3.1.1 Previous Uses of Aerial Photography for Forest Harvest Monitoring.....	15
2.3.2 Satellite Sensors.....	17
2.3.2.1 The Skylab Program.....	18
2.3.2.2 Previous Uses of Skylab Photography for Forest Harvest Monitoring.....	21
2.3.2.3 The Landsat Satellite Program.....	23
2.3.2.4 Previous Uses of Landsat Imagery for Forest Harvest Monitoring.....	28
2.3.3 Summary.....	34
3. <u>METHODS AND MATERIALS</u>	37
3.1 Study Area.....	37
3.1.1 Location.....	37
3.1.2 Climate.....	39
3.1.3 Forestry.....	39
3.2 Indicators of Clearcut Lands.....	42
3.2.1 Spatial Indicators.....	42
3.2.2 Spectral Indicators.....	44
3.2.3 Temporal Considerations.....	47
3.3 Ground Data.....	48
3.3.1 Source.....	48
3.3.2 Compilation.....	48
3.4 Selection of Remotely Sensed Data.....	49
3.4.1 Considerations for Selection.....	49

	PAGE
3.5 Analysis of Remotely Sensed Data.....	50
3.5.1 Aircraft and Skylab Photographic Data.....	50
3.5.2 Landsat Data.....	57
3.5.2.1 Visual Imagery Analysis.....	59
3.5.2.2 Digital Analysis.....	61
3.6 Field Investigation.....	64
4. <u>RESULTS</u>	66
4.1 Analysis of Aircraft Photography.....	66
4.2 Analysis of Skylab Photography.....	74
4.3 Analysis of Landsat Imagery.....	76
4.3.1 Black-and-White Image Analysis.....	76
4.3.2 Color-Additive Viewing.....	84
4.3.3 Digital Image Analysis.....	85
4.4 Comparative Summaries.....	90
4.4.1 Suitability of Imagery Comparison.....	90
4.4.2 Value of Stereoscopic Analysis.....	90
4.4.3 Comparison of Enlargement Techniques.....	93
4.5 Results of Field Investigation.....	94
5. <u>DISCUSSION</u>	97
5.1 Factors Affecting Clearcut Identifiability.....	97
5.1.1 Season of Imagery Acquisition.....	97
5.1.2 Imagery Scale and Resolution.....	98
5.1.3 Imagery Quality.....	99
5.1.4 Spectral Sensitivity and Resolution of Sensor	100
5.1.5 Similarity of Surrounding Land Uses.....	101
5.1.6 Familiarity with Area of Interest.....	102
5.1.7 Revegetation Status.....	102
5.1.8 Topographic and Sun Angle Considerations.....	103
5.2 Factors Affecting Data Selection.....	103
5.2.1 Information Requirements.....	103
5.2.1.1 Thoroughness and Accuracy of Identifica-	103
tion.....	
5.2.1.2 Accuracy of Location Plotting.....	104
5.2.1.3 Detail of Age and Revegetation.....	105
5.2.1.4 Repetition Interval.....	106
5.2.2 Resource Availability.....	107
5.2.2.1 Funds.....	107
5.2.2.2 Equipment and Personnel.....	107

	PAGE
5.3 Potential Methodologies for Clearcut monitoring Using Small Scale Remotely Sensed Data..	108
5.3.1 Methodology I: Detailed Clearcut and Revegetation Survey.....	108
5.3.1.1 Acquisition of Aerial Photography.....	108
5.3.1.2 Selection of Base Map.....	111
5.3.1.3 Location of Clearcuts and Revegetation Assessment.....	111
5.3.1.4 Field Checking.....	112
5.3.1.5 Limitations of Detailed Survey.....	112
5.3.2 Methodology II: General Reconnaissance Survey.....	113
5.3.2.1 Acquisition of Landsat Imagery.....	113
5.3.2.2 Selection of Base Maps.....	114
5.3.2.3 Familiarization with Study Area.....	114
5.3.2.4 Location of Clearcuts and Possible Revegetation Assessment.....	115
5.3.2.5 Field Checking.....	115
5.3.2.6 Limitations of Reconnaissance Survey....	116
5.3.3 Methodology III: Combined Monitoring System	116
5.4 Examination of Potential Transferability of Findings.....	118
5.4.1 Methods and Materials of Comparison Investigation.....	118
5.4.2 Results of Transferability Examination....	119
5.4.3 Discussion of Potential Transferability....	123
5.5 Future Small Scale Remotely Sensed Data Sources.....	124
6. <u>CONCLUSIONS</u>	126
<u>LITERATURE CITED</u>	130
<u>APPENDICES</u>	136
A - Color Formation on Color and Color Infrared Films.....	137
B - Location of Study Areas A and B in the Allegheny National Forest, with the Location of Known Clearcuts and the Year and Acreage of Harvest.....	139
C - Comparative Cost of Small Scale Remotely Sensed Data..	145

LIST OF TABLES

TABLE		PAGE
1	Feasibility of identifying various natural resource features on aerial and space photography with various film types and scales.....	14
2	Skylab film characteristics.....	20
3	Remotely sensed data selected for clearcutting analysis....	51
4	Comparative summary of the accuracy of clearcut identification using various types of small scale remotely sensed data.....	73
5	Comparison of small scale remotely sensed data for the identification of clearcutting and revegetation assessment in Pennsylvania hardwood forests.....	91
6	Comparison of enlargement techniques for clearcut identification in hardwood forests using small scale remotely sensed data.....	95
7	Preferred mission characteristics for acquisition of small scale aerial photography for clearcut monitoring.....	110
8	Remotely sensed data selected for transferability analysis.	121

LIST OF ILLUSTRATIONS

FIGURE		PAGE
1	Spectral sensitivity of normal color and color infrared film, with atmospheric scattering diagram, and vegetation reflectance spectra.....	11
2	Listing and comparison of Landsat multispectral and return beam vidicon spectral sensitivities.....	25
3	Landsat multispectral scanning arrangement.....	27
4	Location of study areas A and B in the Allegheny National Forest, and extent of Allegheny hardwood forests in Pennsylvania.....	38
5	Spectral reflectance properties of selected objects.....	45
6	Master overlay of study site A.....	53
7	Skeleton overlay of study site A.....	55
8	Master overlay of study site B.....	58
9	Comparison of film types and season for identifying clear-cutting and revegetation.....	68
10	Color infrared stereogram of a portion of study area A....	71
11	Skylab earth terrain camera, black-and-white negative of study areas A and B.....	75
12	Skylab multispectral camera color infrared photograph of the study area.....	77
13	Comparison of winter and summer Landsat band 5 multispectral camera images.....	80
14	Comparison of Landsat multispectral scanner band 5 and return beam vidicon imagery.....	82
15	Appearance of clearcuts of different ages resulting from color-additive viewing of same date Landsat MSS images....	86
16	Separation of recent and older clearcuts through color-additive viewing of multi-date images.....	87
17	Separation of clearcuts and farmland through color-additive viewing of multi-date images.....	88
18	Location of study areas in the Adirondack region of New York State.....	120

1. INTRODUCTION

1.1 Statement of Problem

There is much pressure being placed on today's forest resources. Wood pulp is needed to make paper; lumber is needed for the construction of homes for our growing population; and in the face of steadily decreasing supplies and increasing prices of oil, wood is becoming a significant source of fuel. It is anticipated that the demand for all timber products will increase 81% over 1970 consumption in the year 2000, with the demand for hardwoods increasing by 134% (USDA Forest Service, 1973).

In addition to the use of forests for lumber, they are also important for recreation, wildlife, and as watersheds. Fortunately our forest resources are renewable, and can continue to supply our needs if properly managed. Information on the location, amount, and regeneration of harvested lands is needed to allow for the wise management of our valuable timber resources.

There is debate over the value of various harvesting methods as they apply to specific forest conditions. One particular harvesting technique, known as clearcutting, has come under particularly heavy scrutiny. This method involves a nearly complete removal of all trees from a parcel of land in one cutting. It is both praised as a useful and efficient harvesting method for even-aged forest management, and condemned as a destroyer of watersheds, a killer of wildlife, and a

method of "strip mining" our forests (Shepherd, 1975). Due to the concern over clearcutting as a practice, and simply to serve as an aid to the forest land manager, it is important to be able to identify and monitor clearcut lands.

The suitability of various types of small scale remotely sensed imagery, for the identification and monitoring of clearcut lands in predominantly hardwood forests, and for assessing their revegetation*, is investigated using manual and computer aided techniques. A site in the Allegheny National Forest in northwestern Pennsylvania was selected for this study. A second-growth hardwood forest, established after clearcutting and burning between 1890 and 1920, almost completely dominates the area (Marquis, 1975); however, some urban and agricultural development is present.

Although most applicable to relatively homogeneous deciduous forests, it is felt that the information gained on the utility of small scale remotely sensed data for the identification and monitoring of clearcut lands, and their differentiation from other land uses, is extendable to other forested regions where forest harvesting practices remove nearly 100% of the standing timber, where topography is not extremely rugged, and where reflectance properties of the exposed soils and the understory vegetation are distinct from that of the mature

*For the purpose of this study "revegetation" will refer to the establishment of a vegetative cover on a clearcut area, and should not be confused with "regeneration" which implies the establishment of desirable tree species.

forest canopy. It is hoped that forest managers will be able to use the results of this study, directly or by extrapolation to their particular forest situation, to develop appropriate methods of forest harvest monitoring using small scale remotely sensed data.

No attempt is made to judge the value or suitability of clear-cutting as a silvicultural tool. The intent is to provide a source of information for the identification and monitoring of the location, amount, and general condition of clearcut areas for use in making decisions by those people responsible for forest management.

1.2 Objectives

The objectives of this study are: (1) to assess the value of various types of high altitude aircraft photographs, Skylab satellite photographs, and Landsat satellite imagery with regard to sensor, season, and scale, for the identification and monitoring of clearcut areas, and (2) to determine suitable methods for maintaining an inventory of clearcut lands and their revegetation using small scale remotely sensed data.

2. LITERATURE REVIEW

2.1 Forest Harvesting

This study examines the use of small scale remotely sensed data for identifying and monitoring clearcut forest lands, particularly in hardwood forests. It is necessary to understand what clearcutting is, how it appears on the ground, and how it differs from other harvesting methods, as well as something of the controversy surrounding its use, before one can appreciate the need for identifying and monitoring these areas, and approach the task in a credible manner. Information of this sort will be of most value to general remote sensing investigators, who, while understanding remote sensing techniques, may be unfamiliar with forest harvesting methods, but who nonetheless may be required to perform investigations in heavily forested areas.

2.1.1 Forest Harvesting Techniques

Forest or timber harvesting as used in this report refers to the felling and removal of trees from the land on which they had been growing. Although each timber harvesting operation is unique, there are four broad categories into which harvesting methods can be grouped. The choice of method depends on such factors as the tree species, topography, available equipment, economic considerations, and regeneration requirements.

The four main timber harvesting methods are selection or selective cutting, shelterwood cutting, seedtree cutting, and clearcutting. The

following descriptions of these methods are derived from Stoddard (1978) and the testimony of Yurich (1973) before the Sub-committee on Public Lands of the House of Representatives.

Selection cutting is a method whereby certain individual trees are harvested, while the rest of the forest remains essentially undisturbed. Trees are selected based on their quality, position in the stand, and future potential, but it is frequently the case that the oldest and most mature trees are cut. The cutting operation is repeated when younger trees left in the stand reach a harvestable size. This system is applicable to an all-aged or uneven-aged forest.

Shelterwood cutting is a method used mostly in even-aged stands, whereby the stand is removed in two or more cuts over a period of years. Typically during the first, or preparatory cut, the defective and most mature trees are removed to open the stand for accelerated growth. The second, or seed cut, removes most of the timber, leaving only a few trees to provide seed and protection against the elements. The final, or removal cut, removes the remainder of the trees on the site, thereby opening it up for rapid growth of the already established regeneration. The appearance of a shelterwood cut after the removal cutting is similar to that of a clearcut after the establishment of regeneration.

The seedtree harvesting method was considered by Stoddard (1978) to be a variation of clearcutting, but was dealt with as a separate harvesting technique by Yurich (1973). In this method a forested plot is heavily harvested in one cutting, leaving only enough trees to provide seed for the regeneration of the area. Yurich (1973) suggested

that six to ten trees be left per acre. After the regeneration is established the seedtrees are harvested.

Clearcutting is defined as the removal of all trees from a parcel of land in one cutting. After a clearcutting operation there are no marketable trees left in the cutover area. There are basically two types of clearcutting systems; strip clearcutting and block or geometric clearcutting.

Strip clearcutting is the removal of all saleable trees that were growing on parallel strips of land (Leak et al., 1969). Mechanical or chemical processes are sometimes used to remove all trees greater than two inches in diameter at breast height. The sequence described by Leak is one in which the first step involves the removal of trees from every third 50 to 100 foot wide strip of land in the area to be harvested. Two to four years later the second strip is cut. The third strip is cut two to four years after that. Parallel strips of deforested land are an almost certain indicator of strip cut lands.

Block or geometric clearcutting is simply the removal of all of the trees from a forested area in large units, somewhat similar to the pattern of a cookie cutter punching out portions of a piece of dough. These units often have geometric forms not common in a natural forest environment. Knowledge of this tendency is useful for identifying block clearcuts.

2.1.2 Concerns Regarding Clearcutting

During the past decade much controversy has developed over the use of clearcutting as a timber harvesting technique. It is considered

by some to be a raping of forested lands. This is evidenced by the titles alone of such books as "The Clearcut Crisis" (Burk, 1970), "Clearcut, the Deforestation of America" (Wood, 1971), and "The Forest Killers" (Shepherd, 1975). Shortly before 1972, Wyoming Senator McGee introduced a bill to bar clearcutting on all federal lands for a 2-year period during which time the practice was to be evaluated (Gabriel, 1972). On the other hand it is recognized by many that: "Given the right combination of both biologic conditions and economic conditions, i.e. where highly capital-intensive harvest and regeneration practices can be rationally employed, clearcutting can be defended as an optimal management practice." (Bolle, 1972, p. 65). It is also true that under certain circumstances clearcutting is the most efficient method of establishing a desired type of regeneration.

There is obviously truth in the statement that clearcutting has damaged certain forest land by being poorly executed in unsuitable areas; however, it is felt by others that a major reason for the criticism of clearcutting lies simply in the dislike of the admittedly devastated appearance of recently clearcut lands (Ward, 1974; Lang, 1975). This devastated appearance is soon softened and eventually erased by the regeneration of the site.

Twight and Minckler (1972) claim that clearcutting should not be used as a harvesting method in northern hardwoods. Conversely, Ward (1974, p. 77) stated that, "Clearcutting in the hardwood forests of the Northeast is both biologically and economically a desirable timber producing practice when conducted as part of a well-regulated,

even-aged management system." This duality of opinion helps to indicate that further research needs to be done concerning the question of the value and effects of clearcutting. An important element in this task is the ability to quickly and efficiently identify and monitor clearcut areas throughout large regions, so that the amount, location, and, if possible, the condition of the clearcut areas can be inventoried. Small scale remotely sensed data offers the large area coverage desirable for such an inventory.

The actual impacts of clearcutting on the soils, water, wildlife, timber, and aesthetics of Northeastern hardwoods in general, and the Allegheny region of Pennsylvania in particular, will be described in the discussion of the study site chosen for this research (Section 3.1.3).

2.2 Remote Sensing Parameters

In order to select the most suitable forms of small scale remotely sensed data for the investigation of clearcutting, it is necessary to consider certain parameters which are likely to effect the use of imagery for clearcut identification. Foremost among these parameters are the spectral sensitivity of the film or scanner being used, the scale and resolution of the imagery, and the season during which the imagery is acquired. A basic awareness of how these parameters relate to what a user observes on an image will increase his ability to understand why objects or areas of interest appear as they do. This information is most useful to the forest manager who is familiar with the appearance of a clearcut on the ground, but who may be unfamiliar with the acquisition and interpretation of remotely sensed data.

2.2.1 Spectral Sensitivity

A particular film or scanning detector is sensitive to radiation from only a small portion of the entire electromagnetic spectrum. How sensitive a film is at any wavelength is referred to as its spectral sensitivity. Different objects normally reflect different amounts of radiation at any given wavelength. They may therefore appear quite dissimilar on images acquired in different spectral regions. For any given source of radiation, objects whose reflectance is high in the region being sensed will appear lighter on a positive image than objects whose reflectance is low. An object that can be identified as separate from its surroundings in one spectral region may not be identifiable in another (Reeves, 1975).

There are four general types of films used in aerial surveys: panchromatic black-and-white (B&W), black-and-white infrared (BIR), normal color (NC), and color infrared (CIR). Black and white films consist of a single emulsion of silver halide grains held in a gelatin matrix. The emulsion is sensitive to radiation from a target in the visible portion of the spectrum (0.4 - 0.7 μ m). Filters can be used to further restrict the region over which radiation is sensed. Black-and-white infrared films are also sensitive to radiation in the visible portion of the spectrum, but are additionally sensitive to radiation in the near infrared region (0.7 - 0.9 μ m) (Kodak, 1972).

Color films allow the user to view a photograph which represents a scene in the same way that it is seen by the human observer. The color film emulsion is composed of three layers, each of which records reflected radiation in only a portion of the visible spectrum. These

three portions roughly correspond to blue, green, and red radiation. In Appendix A, Figure A1, it is shown how color is recorded on an NC film.

Color infrared films also have a three layer emulsion that is sensitive to independent portions of the electromagnetic spectrum; however, the three bands of radiation that are recorded are the green, red, and near infrared. On the final image, the green radiation received is recorded as blue, the red as green, and the near infrared as red. In Appendix A, Figure A2, it is shown how reflected radiation is recorded on a CIR film.

The different film sensitivities and renditions of a scene can be exploited in order to improve ones ability to detect and delineate features of interest. In this study the features of interest are largely related to vegetation characteristics of the site in question. In Figure 1 it is shown how CIR film might be more useful than B&W or NC film in distinguishing hardwoods, softwoods, and grass, since it records radiation in a region where atmospheric scattering is very low and the reflectance differences of the classes of interest are greatest.

Multi-lens or multiple cameras are sometimes used when it is desirable to obtain simultaneous coverage of an area in more than one spectral range. Different film/filter combinations are used to obtain data in the several spectral regions of interest.

Multispectral scanning radiometers (scanners) also collect radiation of selected wavelengths; however, the image is not recorded directly on film, but rather on a magnetic tape or cathode ray tube from which a photographic image can be produced. Energy from a target

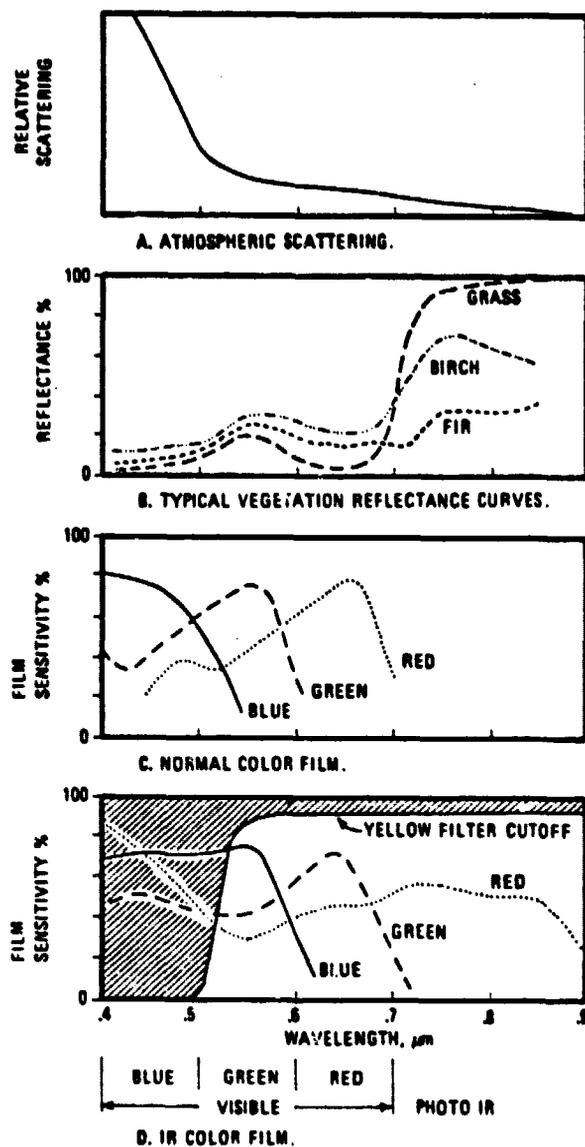


Figure 1: Spectral sensitivity of normal color and color infrared film, with atmospheric scattering diagram, and vegetation reflectance spectra; demonstrating the usefulness of color infrared film in differentiating between fir, birch, and grass. (From Sabins, 1978)

enters the scanner and is split into various portions of the spectrum, by use of a grating and prism. By placing detectors in the proper positions within the instrument, the various bands or channels of radiation can be sensed independently. The spectral sensitivity of a scanner describes where in the electromagnetic spectrum a scanner is sensing radiation, and how finely it can record the variations in radiation being received. Spectral resolution refers to the width of the spectrum being sensed.

2.2.2 Image Scale and Resolution

The scale of a photograph is the ratio of a distance on the photo to that same distance on the ground. Scale is not uniform throughout a photo, due to variations in elevation over the area depicted or due to tilt in the camera at the time of the photography. For convenience, an average scale is often calculated for the photograph. This average scale can be expressed by the equation

$$S_{\text{avg}} = \frac{f}{H - h_{\text{avg}}}$$

where S_{avg} is the average scale, f is the camera focal length, H is the flying height above datum, and h_{avg} is the average terrain elevation. As the flying height becomes greater, changes in terrain elevation begin to have less and less effect on the photo scale (Wolf, 1974).

Spatial resolution refers to some measure of the optical quality of an image produced by a sensor. For a photographic film, the spatial resolving power can be expressed as the number of line pairs per millimeter that can be distinguished on a photo. Although the amount

of information contained in a photo is limited by its spatial resolution, magnification may allow an analyst to observe features recorded on the film that are too small to be seen with the naked eye. For an image acquired with a scanner, the spatial resolution is governed by the scanner's height and instantaneous field-of-view (IFOV). The IFOV refers to the solid angle inside which radiation is sensed by the detector. It defines the smallest area that is independently sensed.

Scale is an important consideration in any usage of remotely sensed imagery, since it affects an image's spatial resolution. The scale of the image must be large enough to allow one to distinguish the object of interest from its surroundings. This ability to resolve an object will obviously also be restricted by the inherent resolution capability of the sensor used to acquire the image. This is demonstrated in Table 1 which shows how scale and film type interact to determine the identifiability of various features.

2.2.3 Season

Season is an important consideration, especially in remote sensing studies involving vegetation. For best results it is important to select a time of year when the features of greatest interest are most discernible. An example in forestry is in the differentiation of softwoods from hardwoods. During the fall and spring, when hardwoods are leafless, they are more easily distinguished from the conifers, than in the summer when both tree types have leaves. In winter this contrast may be masked or enhanced by snow. Image acquisition should be scheduled for the season when the greatest contrast occurs between an object of

TYPE OF RESOURCE FEATURE	Photographic Scale and Film-Filter Combination											
	Scale 1/10,000				Scale 1/30,000				Scale 1/100,000			
	Pan-12	IR-898	Ekta-MF-1	IR Ekta 12	Pan-12	IR-898	Ekta-MF-1	IR Ekta 12	Pan-12	IR-898	Ekta-MF-1	IR Ekta 12
VEGETATION RESOURCES												
Vegetated or not	++	++	++	++	++	++	++	++	+	+	+	++
Wild or Cultivated	++	++	++	++	++	++	++	++	+	+	+	++
Fields with Crops	++	++	++	++	++	++	++	++	+	+	+	++
Fallow Fields	++	++	++	++	++	++	++	++	-	-	-	+
Mature Conifers	++	++	++	++	+	+	++	++	-	-	-	+
Mature Hardwoods	+	++	++	++	-	+	++	++	-	+	-	++
Open Brushfields	++	+	++	++	++	++	++	++	+	+	+	+
Riparian Vegetation	+	++	++	++	+	+	++	++	+	+	+	++
Aquatic Vegetation	+	++	++	++	+	++	++	++	-	+	+	+
Meadow or Grassland	++	++	++	++	+	+	++	++	+	+	+	+
Sparse or Dying Vegetation less than 3 feet high	-	-	+	++	-	-	+	+	-	-	-	+
Vegetation not yet in leaf	-	-	+	++	--	--	+	++	--	--	--	--
Herbaceous Vegetation in standing water	-	++	+	++	-	+	++	++	-	-	-	+
Sprayed Brushfields	+	+	++	++	+	-	++	++	-	-	-	-
Dead or Dying Vegetation greater than 3 feet high	-	+	+	++	-	-	+	++	-	-	-	+
Snags or other downed timber	+	--	++	++	+	--	+	++	-	-	-	-
Burned Areas	+	++	+	++	-	+	++	++	+	+	+	++
Windrowed Brush	++	++	++	++	++	++	++	++	-	-	-	-

Table 1: Feasibility of identifying various natural resource features on aerial and space photography with various film types and scales. **LEGEND** -- ++ - generally and easily identifiable; + - generally identifiable, but often requiring very close study; - - inconsistently identifiable; -- - unidentifiable; Pan - black & white; IR - black & white infrared; Ekta - natural color; IR Ekta - color infrared (From Colwell, 1968)

interest and its surroundings.

2.3 Remote Sensing Systems

2.3.1 Aerial Photography

Aerial photography is acquired with film-holding cameras that are mounted on conventional or high altitude aircraft. Familiarity with photographic methods and products, and the high resolution capabilities of photographs, has led to the extensive use of aerial photography for forest surveys. Aerial photography has been used for forest inventory, classification, volume estimation, damage assessment, and management (Reeves, 1975).

2.3.1.1 Previous Uses of Aerial Photography for Forest Harvest Monitoring

The ability to monitor forest harvesting using large scale aerial photographs has long been established. The Noranda, Quebec, division of the Canadian International Paper Company discontinued the use of ground traverses to monitor cut-over areas in 1958 in favor of 1:15,840 scale aerial photographs. These were found to be both more accurate and economical than the ground traverses (Catto, 1965). The fact that 1:15,840 scale photos are sufficient to allow for tree species identification by determining crown shape from tree shadows (Sayn-Wittgenstein, 1978) would imply that openings in the forest canopy resulting from clearcutting should be clearly visible. A square 1/2 hectare clearcut would be between 3 and 4 mm square on a 1:20,000 scale photo. Not only can clearcuts be identified at these

scales, but the distribution of slash within them can be mapped (Morris, 1970; Meyer et al., 1971).

Although it is clear that large scale aerial photography can provide both accurate and economical information on the location and condition of harvested areas, it is not clear how well small scale imagery can be used to identify and monitor clearcuts in primarily hardwood forests. The successful application of small scale imagery would make investigations of large areas more rapid and economical in comparison to investigations relying on large scale imagery.

In a study about the suitability of small scale photography for forest harvest monitoring, Wightman (1972) found that stereoscopic viewing of CIR photos, taken during the summer at a scale of 1:160,000, was suitable for recording the changes in the forest resulting from logging activities. The strip clearcuts, 100 feet (30 m) in width, slash debris, skid trails, truck roads, and landings were all visible on the photos. When the images were enhanced on an I²S Digicol Viewer, a single channel image evaluation system providing density slicing with false-color enhancement, Wightman was able to identify the progression of logging based on the subtle reflectivity differences between recent cuts where mineral soil was exposed, and previously logged areas where regrowth was well established.

Relatively small changes in cutting boundaries in blackspruce stands in Minnesota were identified on 1:120,000 scale, CIR photographs. The same relatively small (7 to 10 ha) recent cuttings were detectable on 1:500,000 scale, 70mm, B&W and BIR photos (Reeves, 1975).

In order to test the usefulness of small scale photography, Rudd (1971) created a 1:400,000 scale photomosaic of portions of Oregon and Washington from 1:60,000 scale photography. On this simulated small scale imagery he found that he was able to detect cut-over lands due to their distinct spectral signatures, but found them hard to differentiate from burned-over lands.

Aldrich (1975, p. 39) offered the opinion that "land-use changes, regardless of their size, can be detected on 1:120,000-scale Aerochrome Infrared (CIR) film." In his study, he was able to detect harvesting and silvicultural cutting, land clearing, natural regeneration, and artificial regeneration, as well as other disturbance classes, on CIR images of Georgia taken at a scale of 1:120,000 in the month of June. Clearcutting and seedtree cutting could be detected up to 8 years after harvest. Selective logging or improvement cuttings were difficult to detect after 2 years.

The confidence of researchers in the ability of determine land uses, including clearcutting, on photography at a scale of approximately 1:120,000, is demonstrated by their use of it as one source of data against which to compare the accuracy of even smaller scale imagery (e.g. Lee, 1975; Aggers and Kelley, 1976).

2.3.2 Satellite Sensors

For the purposes of this study, "satellite sensors" refers to remote sensing instruments, including photographic cameras, return beam vidicon cameras, and multispectral scanners, carried on earth-orbiting platforms. Data collected by sensors on the manned Skylab

satellite and the unmanned Landsat satellites (formerly Earth Resources Technology Satellite, ERTS) is examined for its suitability for identifying and monitoring clearcutting in hardwood forests.

2.3.2.1 The Skylab Program

The United States National Aeronautics and Space Administration's (NASA) Skylab program was the largest manned space station ever placed in orbit. It was used to conduct astronomical, biological, materials, and earth resources experiments. The station was manned during the spring, summer, and fall of 1973. The information pertinent to the present investigation is the remotely sensed data acquired with the Earth Resources Experiment Package (EREP). Much of the imagery that was obtained was acquired for specific and predetermined studies; however, its usefulness for other applications should not be overlooked and may be viewed with renewed interest since in the mid-1980's the Space Shuttle will again offer the opportunity to acquire space photography. The following information on Skylab is taken from NASA (1974) and Sabins (1978).

The Skylab satellite was launched into orbit on May 14, 1973. It orbited the Earth at an altitude of 435 km and had an orbital path with 50° inclination. This allowed for the acquisition of imagery of the Earth between 50° north and south latitudes. Due to the nature of its orbit, Skylab completed one revolution in 93 minutes, and passed over the same ground point every five days.

The EREP sensors located onboard Skylab included a multi-spectral camera and an earth terrain camera, together comprising the

multispectral photographic facility; a thirteen channel multispectral scanner; an infrared spectrometer; a microwave radiometer, scatterometer, and altimeter; and an L-Band microwave radiometer. Only the multispectral photographic facility and the multispectral scanner were imaging sensors. All films and magnetic tapes were brought back to earth for processing. This discussion will focus on the two components of the multispectral photographic facility since no imagery of the study area was acquired by the multispectral scanner.

The multispectral photographic camera (MSC) assembly consists of six high-precision, optically matched, mounted, and boresighted cameras. Various types of 70mm films and filters were used to produce information in wavelength bands between 0.4 and 0.9 μm (Table 2). The ground coverage of one photograph is 163 km^2 . The scale of the original photos is 1:2,850,000, and can be enlarged more than 10 times with little loss of detail. Estimated resolution of the original films, and estimates of the resolution of second generation reproductions, are compiled in Table 2.

The earth terrain camera (ETC) consists of a single camera sighted so as to photograph an area 109 km^2 within the larger field of view of the multispectral camera. B&W, NC, and CIR photographs were obtained on 11.4 cm films. The nominal scale of the photographs is 1:950,000. Enlargements of 10 to 20 times can be obtained without severe loss of information (Welch, 1976). Table 2 gives the estimated resolution of the original films, and estimates of the resolution of second generation reproductions.

SENSOR	FILTER BANDPASS (μm)	FILM TYPE*	ESTIMATED		GROUND RESOLUTION (m) (SECOND GENERATION) **
			GROUND RESOLUTION (m) (ORIGINAL)	GROUND RESOLUTION (m) (SECOND GENERATION) **	
MSC	0.7 - 0.8	EK 2424 (B&W infrared)	73 - 79	145 ##	145
MSC	0.8 - 0.9	EK 2424 (B&W infrared)	73 - 79	145	145
MSC	0.5 - 0.88	EK 2443 (color infrared)	73 - 79	145	145
MSC	0.4 - 0.7	SO-356 (hi-resolution color)	40 - 46	85	85
MSC	0.6 - 0.7	SO-022 (Panatomic-X B&W)	30 - 38	60	60
MSC	0.5 - 0.6	SO-022 (Panatomic-X B&W)	40 - 46	60	60
ETC	0.4 - 0.7	SO-242 (hi-resolution color)	21	25	25
ETC	0.5 - 0.7	EK 3414 (hi-definition B&W)	17	15	15
ETC	0.5 - 0.88	EK 3443 (color infrared)	30	NA	NA
ETC	0.5 - 0.88	SO-131 (hi-resolution color infrared)	23	30	30

Table 2: Skylab film characteristics.

LEGEND: MSC - multispectral camera; ETC - earth terrain camera; NA - not available
 * - From Eastman Kodak Co.; ϕ - at low contrast; # - From NASA, 1974;
 ** - From Welch, 1974, 1976; ## - resolution losses attributed mostly to
 properties of the duplicating films.

2.3.2.2 Previous Uses of Skylab Photography for Forest Harvest

Monitoring

Sayn-Wittgenstein (1977) noted that relatively little work had been done on the utility of Skylab photography for forestry applications. For this reason it is useful to review the analysis of Apollo 9 multispectral photographs, which are similar in scale and film type to those produced by Skylab. Aldrich (1971) found that Apollo 9 CIR photographs were by far the best for separating forest from non-forest land uses in several study areas in the southeastern U.S. The usefulness of the other films examined, in decreasing order, was as follows; B&W film filtered to detect red radiation, BIR film, and B&W film filtered to detect green radiation. A forest area needed to be 90 m in its shortest dimension in order to be detected on a photo. Colwell and Lent (1969) reached a similar conclusion regarding the relative merits of CIR and B&W films from Apollo 9, but they also felt that if B&W multispectral photos were combined and enhanced, the information derivable was roughly equivalent to that from the CIR film.

A study by Aldrich et al. (1976) was designed to examine Skylab data for forest inventory; however, only one pair of ETC color photos taken in November 1973, and one multiband false-color composite of an MSC scene taken in September 1973 were examined. The photos and the composite were examined monoscopically by conventional photo-interpretation techniques at scales of 1:250,000 and 1:500,000. The ETC photos were also viewed stereoscopically. It was found that the scales and photo types had less effect on the accuracy of evaluating forest resources than expected; however, stereoscopic viewing was found to be helpful

in increasing the confidence in classification. Computer maps were generated by scanning an ETC photo with a microdensitometer, and recording the digitized optical densities on tape. The map was then produced by a computer system developed at Pacific Southwest Experiment Station, using the nearest neighbor theory. "Cutover land" was one of nine classes identified. No ground data were available regarding the amount and location of the cutover lands and so no accuracy check could be made; however, accuracies in discriminating forest from non-forest ranged from 74 to 93%.

NASA (1978) reported that it is feasible to differentiate major timber classes, including "cut", through density-slicing analysis of MSC and ETC natural color and color infrared photos, provided that they are at scales of 1:24,000 or greater.

MSC composites were found to be nearly as effective as individual ETC films in a land use study, which included forest categories in central New York (Hardy et al., 1975). Color ETC photos were considered superior in terms of interpretation preference, while ETC B&W photos had the best resolution properties.

Clearcut areas in Douglas-fir stands could best be identified on CIR photos, on which they appeared blue due to low IR reflectance. Photographic enhancement of B&W images, by an image ratioing technique, which enhances certain spectral bands while suppressing others, allowed for better observation of the clearcuts, as well as some assessment of their condition based on subtle variations in color (NASA, 1974).

Carnegie and Fine (1977) reported that Skylab crewmen experienced difficulty in distinguishing between different forest cover types, but that they could distinguish boundary lines of clearcuts, especially in Washington State and in New Zealand where clearcutting produced distinctive blocks in uniform areas of conifers. Snow cover helped make the clearcuts in Washington more visible.

These previous studies leave some doubt as to the usefulness of Skylab photography for the monitoring of clearcut areas. The resolution of the photographs may make them inadequate for detailed clearcut monitoring. The limited number of studies performed using this data source may also reflect a lack of usefulness; however, it may simply be a result of the greater interest on the part of investigators to examine the usefulness of the coverage provided regularly by Landsat, rather than the non-repetitive coverage of Skylab. It is necessary to evaluate the usefulness of satellite photography for clearcut identification, since beginning in the mid-1980's the Space Shuttle will again make available, on a possibly repetitive basis, new space photography. The Large Format Camera (LFC) is intended to provide photos covering 225 by 450 km per frame at a scale of 1:1,000,000 (similar to the ETC) and a resolution of 15m (1 to 2 times improvement over the ETC depending on film type) (Doyle, 1978).

2.3.2.3 The Landsat Satellite Program

NASA's first Earth Resources Technology Satellite was put into earth orbit on July 23, 1972, and designated ERTS-1. Since that time one or more such satellites, renamed Landsat, have been continuously

providing imagery of the earth's surface from orbital altitudes.

Landsat-2 was launched in January, 1975, and Landsat-3 was launched in March, 1978. Built with a design life of one year, Landsat-1 continued to function until January, 1978, while Landsat-2 was deactivated early in 1980.* Landsat-3 is presently the only operational satellite. The next Landsat satellite is not scheduled to be launched until mid 1982 (Covault, 1980). The following information on the Landsat system and its sensors is taken from the Landsat Data Users Handbook (U.S.G.S., 1979), Lillisand and Kiefer (1979), and Sabins (1978).

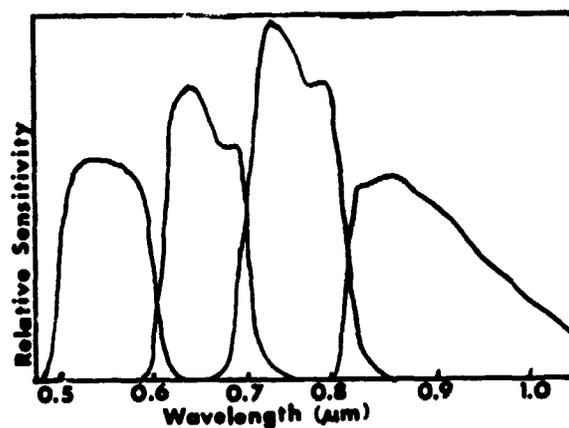
The Landsat satellites orbit the earth at an altitude of 920 km with a 9 degree inclination, which allows them to gather information for all parts of the earth except the areas between 82 and 90 degrees north and south latitudes. The sun-synchronous orbit is established so that the satellite's ground track repeats its coverage of the earth at the same local sun time every 18 days. Variations in illumination still occur due to seasonal variation in sun angle. If more than one satellite is operational, the period of locational repetition will be reduced. Through orbital corrections the image center points are maintained within 37 km.

Two types of remote sensing instruments, a multispectral scanner (MSS) and a return beam vidicon camera system (RBV) are carried on the Landsat satellites.

The Landsat MSS is a line scanning device which senses reflected radiation in four spectral bands (Figure 2). The scanner's mirror continuously scans the earth in a 185 km swath normal to the satellite's

*The June 30th, 1980, issue of Aviation Week & Space Technology reports that Landsat-2 has been reactivated.

<u>BAND</u>	<u>SPECTRAL SENSITIVITY (μm)</u>
MSS 4	0.5 - 0.6
MSS 5	0.6 - 0.7
MSS 6	0.7 - 0.8
MSS 7	0.8 - 1.1
RBV 1 (Landsat -1 & -2 only)	0.475 - 0.575
RBV 2 (Landsat -1 & -2 only)	0.580 - 0.680
RBV 3 (Landsat -1 & -2 only)	0.690 - 0.830
RBV (Landsat -3 only)	0.505 - 0.750



MSS Bands 4 through 7, relative sensitivities

Figure 2: Listing and Comparison of Landsat Multispectral (MSS) and Return Beam Vidicon (RBV) Spectral Sensitivities.
(From Salerno, 1976; U.S.G.S., 1979)

orbital path. The along-track progression of the scan lines is provided by the forward motion of the satellite. Four arrays, each with six detectors, are employed to scan simultaneously six lines in each of the four spectral bands (Figure 3). The combination of each detector's instantaneous field-of-view, and the satellite's altitude, result in a 79 by 79 m ground resolution cell or pixel. This pixel size determines the systems spatial resolution. The analog signals resulting from the MSS response to the amount of reflected radiation received, are converted into digital form and either relayed directly to earth or stored onboard for later transmission. When received on earth, the imagery is processed in such a way as to produce individual images covering 185 km² with 10% endlap. The nominal scale of an MSS image is approximately 1:3,369,000.

The RBV systems on Landsats-1 and -2 consisted of three television-like, simultaneously operated cameras, each sensing radiation in a different spectral band (Figure 2). Images were exposed by a shutter mechanism onto a photosensitive surface which was then scanned by an electron beam to produce a video signal. The cameras of the RBV were stationed so as to view the same 185 by 185 km ground area that was being simultaneously imaged by the MSS. The ground resolution of the RBVs was 80 m, with a nominal scale of 1:1,684,000.

Landsat-3 has a two-camera RBV system which records data in the same way as the unit on the first two Landsat satellites; however, both of the cameras are sensitive to the same portion of the spectrum. The two cameras provide side-by-side images each approximately 99 km on a

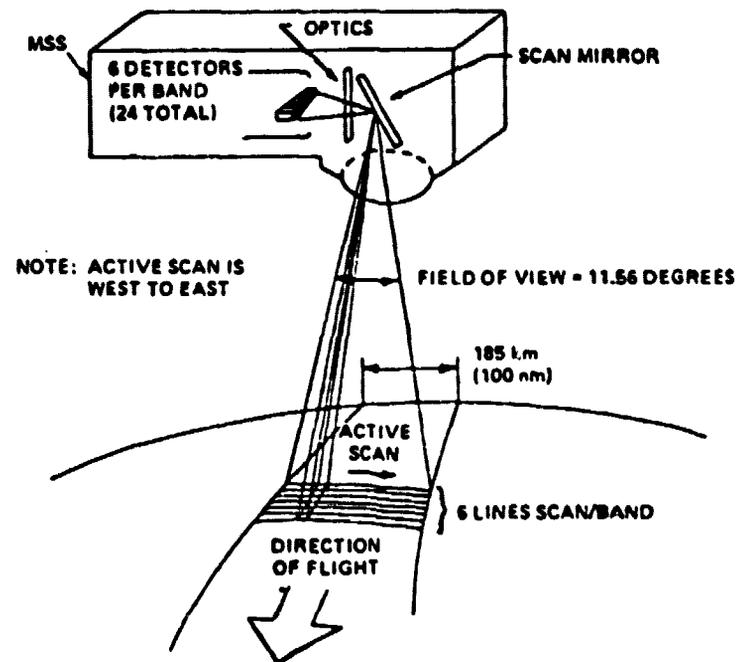


Figure 3: Landsat Multispectral Scanning Arrangement
(From U.S.G.S., 1979)

side with 30 m ground resolution. Four RBV images are required to cover the area depicted on one MSS image. The improved resolution and larger scale of the Landsat-3 RBV images in relation to MSS or Landsat-1 or -2 RBV images, may stimulate interest in this sensor.

2.3.2.4 Previous Uses of Landsat Imagery for Forest Harvest Monitoring

The identification and monitoring of clearcut lands and their regeneration has been the focus of certain studies using Landsat MSS data, and a by-product of many other forest classification studies using various forms and combination of MSS imagery.

In addition to manual photo-interpretation of B&W and enhanced MSS imagery, there are also two general methods of computer classification of digital data, supervised and unsupervised. In supervised classification, the user works closely with the computer by developing numerically the spectral attributes (signature) of a feature of interest. The signatures are arrived at by examining areas whose identities or cover types are known (training sites). Unsupervised classification, or cluster analysis, allows the computer to divide the digital data into groups by identifying natural clusters of reflectances. The clusters are compared to known ground conditions and thereby assigned to a land use/cover class of interest. After signatures are developed for the classes of interest by either method, the computer is used to classify the entire area being examined.

In the only study encountered that dealt with the monitoring of clearcutting in the northeastern U.S., Bryant et al. (1979) found that

they could distinguish among recent clearcuts, clearcuts with early regrowth, clearcuts with advanced regrowth, and softwood clearcuts in northern New Hampshire using supervised digital analysis of Landsat summer imagery. Because of tonal variations present in clearcuts resulting from the intensity of harvest or the level of regrowth, 12 clearcut signatures needed to be developed in order to sufficiently classify the clearcuts in the study area. Much adjusting was needed to arrive at these signatures, which were then grouped into the four categories mentioned. Clearcuts were represented on a classification map by a mixture of symbols representing the various clearcut categories. In order to see if the identification procedure was reproducible for monitoring purposes, they examined a later MSS image by using new training sites and by trying to match the overall appearance ("fudging") of the later image with the earlier image through computer modification. The remaking of class signatures using new training sites worked fairly well, while the fudging method did not yield good results.

The results of the study by Bryant and her colleagues (1979) are useful in that they demonstrate that clearcutting can be identified in areas of hardwood forest using supervised classification of digital data. The apparent difficulty in developing signatures for clearcuts, and in achieving uniform classification of clearcut areas, makes it important to determine if other data sources, seasons of imagery, or analysis methods would offer more accurate or economical results in identifying clearcut lands in predominantly hardwood forests.

Y. Jim Lee has done much work using MSS data for identifying clearcutting and monitoring its progression in Canadian forests (See Literature Citations). By analyzing band 5 images taken in late summer approximately one year apart, he overestimated areas clearcut in the intervening year by 12.9%, and those cut more than one year ago by only 2.2%. Color additive viewing of the imagery assisted him in his interpretation, especially of areas cut within the last year (for a brief discussion of color additive viewing see section 3.5.2.1). The smallest clearcut that he mapped was 11 ha, and the total clearcut area was overestimated by only 4.2% (Lee, 1975).

Using the Image 100 interactive multispectral analyzer, Lee (1976) found unsupervised classification of the images unsatisfactory for clearcutting studies. Using supervised classification he was able to distinguish the two clearcut classes mentioned above. In 1977, Lee et al. reported success in detecting and monitoring clearcutting by using "principal components color enhancement," and by analyzing multi-date MSS imagery from bands 5 and 6. He found that the use of digital tapes was much more reliable than overlaying the multi-date images and visually analyzing them. The size of the clearcuts he detected ranged from 1.2 ha to 154.2 ha.

In a study of a forested region in Oregon, Hawley (1979) found that bands 5 and 7 were most useful in investigating clearcutting. Using a supervised classification system, Hawley found that he could detect clearcuts and areas of regeneration by variations in their reflectivities. The detectability of regeneration depended on its

height, crown-width, percentage ground cover, and mostly on its spatial distribution. Light and heavy brush often could be differentiated, whereas partial tree canopy removal was difficult to detect. The results of a pixel by pixel accuracy check of 5% of the identified clearcuts indicated that 92% of the pixels accurately represented the true ground condition.

The suitability of Landsat MSS images for monitoring the progress of clearcutting on Vancouver Island, British Columbia, was investigated by Murtha and Watson (1975) for a completely forested area in which clearcutting activities were unlikely to be confused with other land uses. Band 5 alone was found to be inadequate for the mapping of clearcuts. By combining the 70mm transparencies of different bands (especially 5 and 6) in a color additive viewer, they were able to recognize four mapping classes; recent logging, second growth, old second growth, and over-mature timber. Examining the images in the color-additive viewer at a scale of 1:150,000, allowed them to determine eight regeneration canopy cover classes, which included estimations of the percent of vegetative cover on recent clearcuts. Inter- and intra-image distortions created problems in accurately mapping the locations of the clearcuts. Despite the mapping problems, "It was concluded that monitoring of the progression of clearcutting at the enlarged scale not only involved estimations of relative locations, but permitted an estimate of revegetation, or locating areas of poor regeneration" (Murtha and Watson, 1975, p. 257).

Lee (1975) and Kalensky et al. (1979) found that information on clearcutting and/or regeneration can be derived from manual interpretation

of MSS imagery, but Heath (1974) found manual photo interpretation to be largely unsuccessful. Many investigators hold that examination of digital MSS data yields more satisfactory results than manual analysis of MSS photographic products in forestry applications, including clearcut identification (Sayn-Wittgenstein and Moore, 1972; Heller, 1975; Hawley, 1979). This is likely to result from the higher spatial resolution and better spectral sensitivity provided by the digital analysis of the Landsat data, and its suitability for quantitative remote sensing.

Supervised classification of digital data was found to yield significant information on clearcutting in studies by Kan and Dillman (1975), Williams (1976), Lee (1976), Bryant et al. (1979), and Hawley (1979). Unsupervised classification was generally found to be unsatisfactory by Heath (1974), Lee (1976), Lee et al. (1977), and Kalensky (1979). Johnson et al. (1979) used an unsupervised classification system, and were able to classify clearcuts and reproduction with accuracies of 85 and 87% respectively, even though most of the misclassifications in their overall study were between clearcuts and regeneration. It is now possible in several minutes time, to isolate clearcut areas in British Columbia using Landsat digital data and the GEMS 300 image analysis system (Lee, 1980).

Multi-date image analysis was found by most researchers to be far superior to single-date analysis in the study of clearcutting (Kirby, 1973; Kan and Dillman, 1975; Lee et al., 1977; Williams, 1979). The selection of MSS bands for optimum clearcut differentiation is an

important consideration. Kalensky and Scherk (1975) found bands 5 and 7 to yield basically the same information as bands 4, 5, 6, and 7. Bands 5 and 7 were also favored by Heller (1975), Lee (1975), and Hawley (1979).

Seasonal variations were found to effect the ability to detect and monitor clearcutting. Aldrich et al. (1975), in their study in Georgia, concluded that early or late spring imagery was best for detection of forest disturbances, followed by late fall to late winter, and lastly by summer imagery, which they felt was of little worth due to oversaturation with IR reflectance. It appears that many researchers favor the growing season for their studies (Murtha and Watson, 1975; Lee, 1975, 1976; Lee et al., 1977; Bryant et al., 1979; Hawley, 1979; Johnson, 1979). Williams (1979) was able to extract spectral signatures for clearcuts and pine regeneration on both summer and snowfree winter imagery.

The minimum size of clearcuts detected in various studies was 11 ha (Lee, 1975), less than 2 ha (Aldrich, 1975), and 3 ha (Bryant et al., 1979). Accuracies of the results of these studies are important, and are generally determined by comparing ground data to the Landsat classification and determining the number of correctly identified areas as a percent of the total number of that type of area present. Williams (1976) claimed 54 and 59% accuracies in mapping clearcut land and regeneration respectively using 8 band multi-date analysis. Using a cluster analysis, Johnson et al. (1979) calculated 85 and 87% accuracies for clearcuts and regeneration. Using standard MSS color composites and photo-interpretation techniques, Aldrich (1975),

was able to obtain 71 and 25% accuracies for harvested and regenerated lands. These lands, harvested using the seedtree or clearcutting method, could be detected up to 8 years after harvest. Finally, Hawley (1979) claimed 92% accuracies for clearcut areas using supervised classification.

Little emphasis has been placed on the study of Landsat RBV data, possibly as a result of the limited amount of imagery available from Landsat-1 and -2, and the short period of availability of RBV data from Landsat 3.

2.3.3 Summary

The literature contains evidence that some success has been achieved in the identification and monitoring of clearcutting, and in the assessment of revegetation, by investigators using virtually all types of small scale (1:120,000 or smaller) remotely sensed data, as well as a variety of analysis techniques.

Small scale aerial photography seems very well suited for the monitoring of clearcutting and subsequent revegetation studies in clearcut areas. Color infrared photography flown during the summer at scales of 1:120,000 to 1:160,000 seems to be most often used. The scale and resolution of this photography allows for the detection of clearcuts on the order of one hectare, differentiation of clearcuts from other land uses, and relatively precise revegetation assessment. The limited studies of Skylab and Apollo photography indicate that it too can be successfully used to identify clearcuts in certain regions.

While researchers seem united in the opinion that Landsat MSS imagery can be used for clearcut identification and monitoring, they have reached different conclusions concerning the usefulness of the various ways of analyzing the data for this purpose. The manual analysis of black and white Landsat images, or their analysis using color-additive viewing, has been found quite useful by some. Multi-date analysis of summer images of band 5 and band 6 or 7 seemed to be preferred. Many researchers feel that digital analysis using supervised classification is the preferred method of analyzing MSS data for clearcut monitoring, because of the higher spatial resolution, better spectral sensitivity, and ease of data manipulation provided by digital analysis, and the ability to work closely with the computer when doing supervised classifications.

The majority of previous studies performed have been concentrated in the largely coniferous forest regions of Canada and the northwestern U.S., and in the pine regions of the southeastern U.S. Certain study sites included land uses that might be confused with clearcutting, while many did not. Past research has emphasized the usefulness of one data type and/or method of analysis for clearcut identification, rather than comparing the various data types and/or methods of analysis, and determining their relative strengths and weaknesses for clearcut identification and revegetation assessment.

The present study was designed to determine and compare the usefulness of various types of small scale remotely sensed data for the identification and monitoring of clearcutting in predominantly

hardwood forests. Additionally it was of interest to determine what information regarding revegetation can be derived from these data sources, and how well clearcut areas can be distinguished from other land uses present in an area of interest. Several methods of analysis were also investigated to determine their relative merits.

3. METHODS AND MATERIALS

3.1 Study Area

3.1.1 Location

In order to assess the usefulness of small scale remotely sensed imagery for identifying and monitoring clearcutting in hardwood forests, two study sites were selected with the Allegheny National Forest, located on the Allegheny Plateau in northwestern Pennsylvania (Figure 4). The selection of two sites was required due to the incomplete nature of remotely sensed imagery, or lack of suitable ground conditions for one site alone.

The study site boundaries are generally located so as to include the areas of the Sheffield Ranger District forest compartments which were used as sources of ground data for this investigation. Site A, used for the analysis of all data types except Landsat imagery, is located just south of the Allegheny Reservoir in the Sheffield Ranger District. Site B, used for the Landsat analysis, is located in the Sheffield District just south and west of Sheffield, Pennsylvania (Figure 4). Site A is an area of approximately 180 sq. km, while Site B is approximately 130 sq. km in size. Cutting records were available for roughly 35% of Site A, and 70% of Site B. The remainder of each area was either in private ownership or under the jurisdiction of a neighboring ranger district. See Appendix B for a more detailed illustration of the study areas and locations of the clearcuts within them.

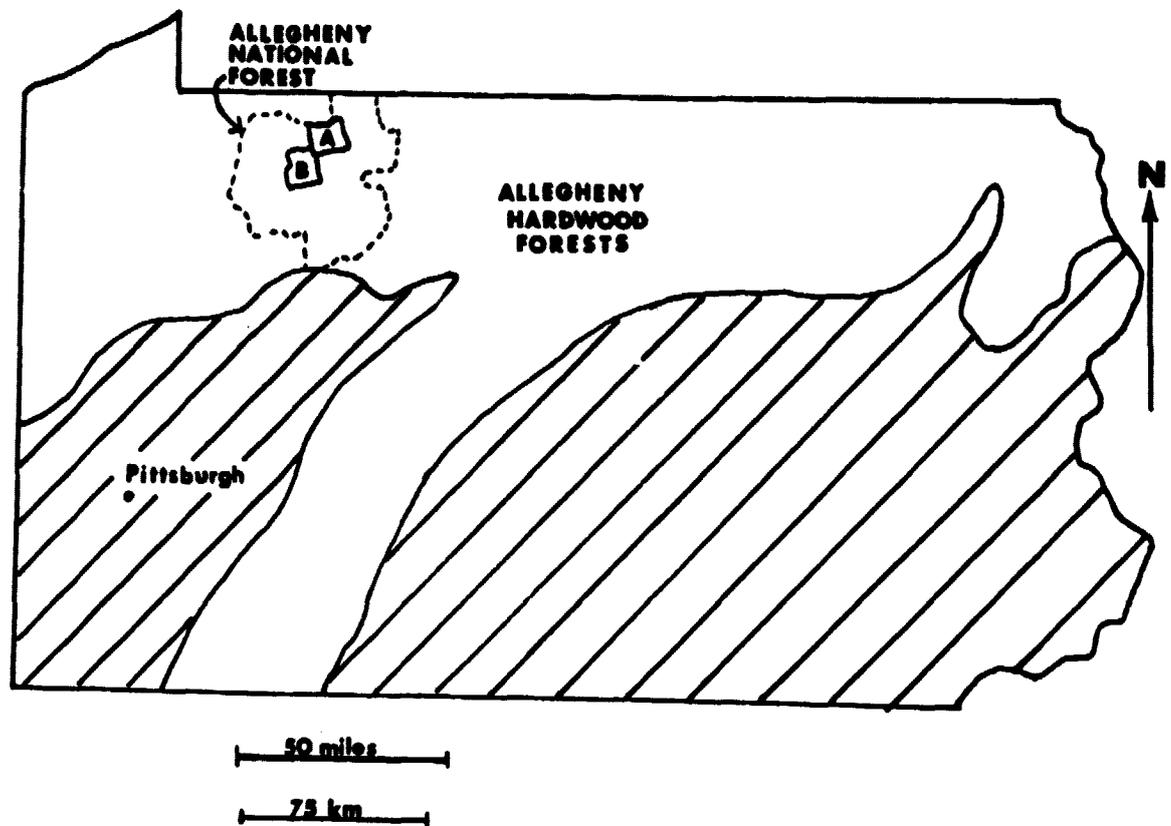


Figure 4: Location of study areas A and B in the Allegheny National Forest, and extent of Allegheny hardwood forests in Pennsylvania. (Center of National Forest approximately $79^{\circ} 00'$ W longitude, $41^{\circ} 40'$ N latitude) (From Marquis, 1975)

3.1.2 Climate

Examination of climatological data and discussions with members of the staff of the Sheffield Ranger District, yielded information regarding those general components of the local climate considered relevant to this study. It is usually well into May before leaves are present on the trees, while fall coloration typically appears during the first or second week of October. Leaves are often shed very soon after this time. The full foliage period, the period chosen by many investigators to monitor clearcutting using remote sensing techniques, therefore extends roughly from June through September. Snow typically begins to accumulate on the ground in December or early January, and remains through much of March. The local climate is typically wet through most of the year, with a total annual rainfall of approximately 35 to 40 inches. The fact that there are only nine cloud-free Landsat images which include the study area is an indication that the area may be under cloud cover a fair amount of time.

3.1.3 Forestry

The forests in this region are largely composed of sugar and red maple, beech, white ash, black cherry, and other hardwood species. Hemlocks are also found occupying the more moist areas in the valley bottoms (Gordon, 1937). These second growth hardwood forests grew to replace the original forests which were almost completely clearcut between 1890 and 1920, in what is described as the highest degree

of forest utilization in a commercial lumber area that the world has ever seen (Marquis, 1975). The heavy cutting and frequent, and repeated fires that occurred during this time favored the growth of hardwood species over conifers (Marquis, 1975). The timber growing in this region is now reaching maturity, and forms the basis of a wood industry that adds 275 million dollars to the economy each year (Penn. Dept. of Commerce, 1972).

Clearcutting of timber is presently one method of forest harvesting in the Allegheny Forest and Pennsylvania, and appears to be a method that will continue to be used (Northcross, 1979; Nelson et al. 1975), despite the claims of certain researchers that other harvest techniques are more suited to harvesting in northern hardwoods (Marquis, 1979; Metzger and Tubbs, 1971). It is important to be aware of the effects of clearcutting on the forest environment in which it is utilized. The statements that follow are based on studies of clearcutting in Pennsylvania or the Northeast in general.

Aesthetically, clearcutting is unappealing because of the devastated appearance of a recently clearcut section of forest. In Pennsylvania it takes from 3 to 10 years for a clearcut to resemble a young forest rather than a cut over area (Lang, 1975). Soil loss due to erosion is often cited as a reason for concern over clearcutting. District foresters in Pennsylvania felt that erosion problems are generally minor and can be corrected if roads are properly retired after logging is completed (Pennock et al., 1975). These feelings are supported by the finding that the majority of evidence indicates that

soil losses in eastern forests are slight compared to those caused by other land uses (Patric, 1976). Lynch et al. (1975) concluded that clearcutting in Pennsylvania does not pose a serious threat to watershed values as long as certain basic precautions are taken. These findings are again similar to those concerning the impacts of harvesting on water quality in other parts of the eastern United States (Corbett et al., 1978). Concern about the possible detrimental effects of clearcutting on Pennsylvania's wildlife resources seems unfounded since, through intelligently planned spatial and temporal distribution of clearcuts, a diverse habitat for numerous species can be created and maintained (Hassinger et al., 1975).

Regeneration of clearcut sites in certain parts of the study area is unsatisfactory, with the lands coming back either to trees of an undesirable species composition, very few trees, or virtually no trees at all (Marquis, 1975; Gearhart, 1980). Two suspected reasons for this are insufficient regenerated growth at the time of harvest, and overgrazing of the regeneration by deer. The monitoring of these poorly regenerated areas is an important concern. Site preparation is performed on certain clearcuts in order to aid their regeneration. This may result in clearcuts more visible on remotely sensed imagery by creating greater soil disturbance and removing more total vegetation than would result from clearcutting alone.

3.2 Indicators of Clearcut Lands

In a remote sensing analysis there are three sources of information that need to be considered when addressing a resource or land use monitoring problem. These are spatial indicators, spectral indicators, and temporal considerations. Spatial indicators are the shapes and configurations of objects which help one in determining their identity, while spectral indicators are the tones recorded for objects due to their reflectance properties. The texture of an area or object on a photo or image, is a result of both spectral and spatial indicators, and is a valuable aid in the identification of areas of interest. Temporal considerations are those factors of timing that must be considered in the collection and assessment of remotely sensed data for a given purpose.

Described below are the considerations relevant to the identification and monitoring of clearcutting in dominantly hardwood forests.

3.2.1 Spatial Indicators

The most distinctive and easily seen spatial indicators of recently clearcut or somewhat regenerated or revegetated lands are the sharp unnatural geometric openings in the forest canopy. These typically take the form of blocks or strips. It is best to inspect images for the presence of clearcut, regenerated, or revegetated areas with the use of a stereoscope, since this allows the observation of height variations in the vegetation present. An area which appears homogeneous when viewed monoscopically, may be seen to have blocks or strips of shorter vegetation, indicating revegetation, when viewed stereoscopically. For small scale imagery it is most useful to use

a stereoscope with significant magnification abilities, rather than a simple pocket stereoscope.

Other spatial indicators of clearcutting, that may be visible at least at the larger scales being considered in this study (1:120,000) are (1) lines of disposed slash, (2) skid trails and logging roads, and (3) loading areas.

Other events or practices may effect forested areas in ways that make them appear similar to clearcut lands. Certain spatial indicators may be of help in differentiating clearcuts from such areas. Wind-throw can level all or most of the trees in a portion of a forest; however, the debris will not be neatly placed in rows as is often the practice with slash disposal, nor will the boundaries of the effected area resemble the linear boundaries of a clearcut. Disease can denude trees but will typically leave them standing. The plowing or contour patterns of farmed lands may be visible and therefore an aid in differentiation. Texture would likely be useful in differentiating between carefully cared for agricultural lands and less carefully managed areas of forest harvesting.

It is important to be aware that the value of spatial indicators will become less as one analyzes smaller scales of imagery, because of losses in spatial resolution. At low spatial resolution, spectral indicators will become the dominant source of information for the detection of clearcut areas.

3.2.2 Spectral Indicators

The key to distinguishing recently clearcut and regenerated or revegetated lands from surrounding forests is the ability to discern between the responses in reflectivity of these areas in one or more wavelength bands. The greater the difference in reflectivity, the easier and more certain will be the separability and identification of these areas. In the period immediately after clearcutting there will be a good deal of exposed soil. This stage should be followed by a ground cover of grasses, weeds, shrubs, and young regeneration. Finally the area will be dominated by young trees which will gradually grow to resemble the mature forest around them.

The spectral reflectance of various objects over the range of .4 to .9 μm (blue to reflected infrared radiation) is shown in Figure 5. Shown as envelopes of spectral values are the generalized reflectance curves of deciduous and coniferous trees. Their difference in reflectivity in the infrared region allows one to determine with relative ease when one is looking at a fairly homogenous deciduous or coniferous forest. For the present study it is important to examine how an area will appear after clearcutting and the reestablishment of a vegetative cover with regard to the surrounding uncut deciduous forest.

Bare soil will be present over much of a recent clearcut. In Figure 5 are seen the reflectance curves of two soils, one dry and one both wet and dry. The dry soils, though notably different in their responses at various wavelengths, are most distinct from the deciduous trees in the red region. In the infrared region, dry soil (A) would

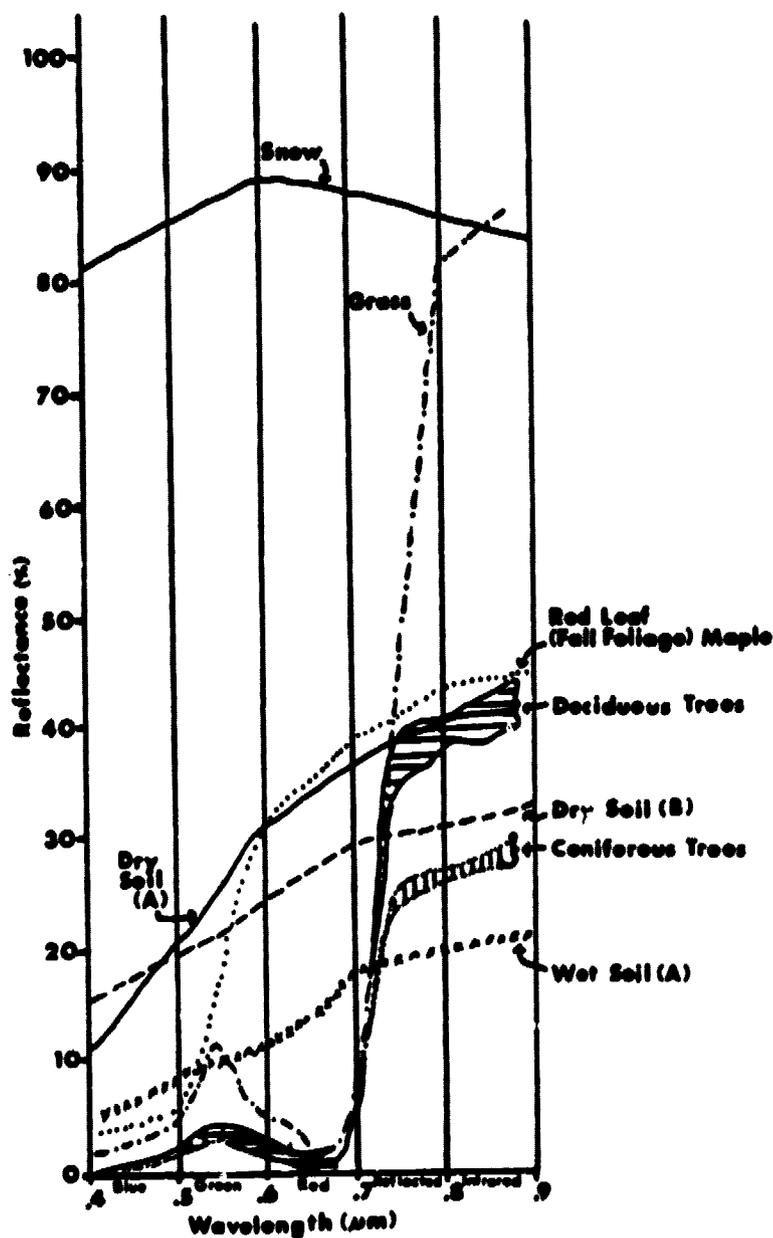


Figure 5: Spectral reflectance properties of selected objects. Sources: Deciduous and Coniferous trees, Dry Soil (B), Lillesand and Kiefer, 1979; Snow, Kondratyev, 1969; Grass, Salerno, 1976; Wet and Dry Soil (A), Condit, 1970; Fall Foliage, Knippling, 1969.

be spectrally indistinguishable from the deciduous trees, while the same soil, if wet would allow for much greater separability in this region. Overall bare soil can best be distinguished from deciduous trees in the red and infrared regions.

When a clearcut area begins to revegetate it is likely that grasses, shrubs, and very young trees would be the dominant vegetation. Unfortunately no reflectance curves for shrubs or young trees could be found. It is evident however from the ability of prior researchers to distinguish these features from mature forest, that their signatures are unique from those of the surrounding trees. The signature for grass shows that it has a very high reflectance in the infrared region thereby making it distinguishable from forested areas in this band.

Textural variations in an image, resulting from differences in canopy structure or lack of a canopy, may at times be of value in differentiating between uncut, recently cut, and regenerated or revegetated forest lands. On aerial photos young trees often exhibit smooth, uniform textures, while more mature, older forests appear rougher in texture. Texture on a Landsat image is a result of the variation in tone between pixels resulting from different forest types or conditions in a given area. Since the instability, competition, and change often found in areas of young trees results in higher levels of variance than results from mature forests, young forest stands are generally rougher in texture than mature forests (Strahler et al., 1979). Areas with no tree cover, such as recently clearcut areas or farmed areas, are likely to exhibit textures different from those of forested areas.

C-2

Scale and resolution are also very important considerations. The areas dominated by a particular ground cover must be large enough to be seen on a photograph or resolved on a multispectral image as a distinct entity, without being lost through blending with the reflectance of the surroundings. If the spectral response of an object is great enough, it may be detectable even if it is smaller than the normal resolution capability of the sensor.

3.2.3 Temporal Considerations

The timing of the acquisition of imagery significantly effects the potential usefulness of both spatial and spectral indicators. The spatial indicator of sharp boundaries may be lost or made significantly harder to detect in a deciduous forest if the imagery is taken during a period when the trees are leafless. Instead of seeing the easily distinguishable tree canopy, one will be able to see the ground through the leafless branches. The leafless condition will also greatly effect the ability to spectrally differentiate cut and uncut lands. Whereas the reflectance from leaves is distinct from that of clearcut areas, the reflectance from the ground in the cut and uncut areas may be very similar.

Seasonal, and even daily variations in reflectivity, can effect the ability to detect clearcut areas. The separability of recently clearcut areas from their surroundings may be enhanced or lessened by acquiring imagery during a wet season or after a rain, due to changes in the reflectivity of the soils (see Figure 5). The presence of snow, whose reflectivity is very high at all wavelengths being

considered (Figure 5), could dominate an image so that the features needed to identify a clearcut would be undetectable; or it could enhance detectability of clearcuts where there are no trees to interfere with the radiation striking or being reflected from the snow. Fall coloration of deciduous leaves (Figure 5) could also hinder or aid detection depending on the condition of the soil and other vegetation at the time.

3.3 Ground Data

3.3.1 Source

The source of ground data for this study is the harvesting records kept by the Sheffield Ranger District in the Allegheny National Forest. The district is divided into compartments which are further divided into sites. Records of timber harvests, salvage cuts, and improvement cuts that occur within the sites are kept both in the form of a written description which includes the acreage cut, and in the form of compartment maps on which are indicated the location, shape, type, and year of harvest, as well as the year during which any site preparation was conducted in an effort to aid regeneration. The base maps used for the compartment mapping show ownership patterns, roads and streams, and are at a scale of 1:15,840 (4 inches to the mile).

3.3.2 Compilation

Compartment maps were obtained from the Sheffield Ranger District for study sites A and B. These maps indicated the location and year of cutting activity in the area of interest. The fact that a separate

map is maintained for each compartment results in a very fragmented pictorial display of the harvesting history of an area larger than two or three compartments. In order to create a pictorial record of cutting in which the locations of cuts could be easily seen in relation to the cutting activities in other compartments, the information from the compartment maps was transferred to a map of the National Forest at a scale of approximately 1:125,000. The mapping of the cuttings at this smaller scale was also done in order to help facilitate the comparison of the very small scale remotely sensed imagery to the ground data.

Appendix B contains detailed information of the study areas within the Allegheny Forest, the location of the known clearcuts within the study areas, and tables showing the year of harvest and acreage for each cut.

3.4 Selection of Remotely Sensed Data

3.4.1 Considerations for Selection

Selection of the remotely sensed data was based on insights gained from previous studies, and by the desire to obtain aircraft, Skylab, and Landsat imagery from the greatest possible variety of sensors, seasons, and scales. Information on the availability of imagery was obtained from the EROS Data Center in Sioux Falls, South Dakota, in the form of computer listings showing the dates and condition (percent cloud cover and image quality) of the imagery acquired of the geographic area of interest.

Imagery was selected based on date of acquisition, spectral sensitivity, percent cloud cover, scale, image quality, and image availability in the format desired. Imagery was purchased from the EROS Data Center. All imagery, with the exception of a Landsat MSS computer-compatible tape, was in the form of positive transparencies, in order to facilitate enlargement and photographic reproduction. A list of the remotely sensed data obtained for the study area and analyzed in this study is reported in Table 3.

3.5 Analysis of Remotely Sensed Data

3.5.1 Aircraft and Skylab Photographic Data

The photographic transparencies of study site A, taken from aircraft and Skylab, were analyzed both monoscopically and stereoscopically.

Using an overhead projector (Transopaque Auto Level) the images were enlarged to a scale of approximately 1:125,000 to allow for more detailed viewing, while at the same time facilitating the comparison of the information derived from the images to that provided by the ground data plotted on the Allegheny National Forest map.

A matt acetate overlay of study site A was created by tracing the site's boundaries from the Allegheny National Forest map. Shown on the overlay were the Allegheny Reservoir, the Seneca Pumped Storage Reservoir, key roads and pipelines, and private and National Forest lands for which no cutting records were available (Figure 6). This overlay was used to determine if an identified clearcut was located

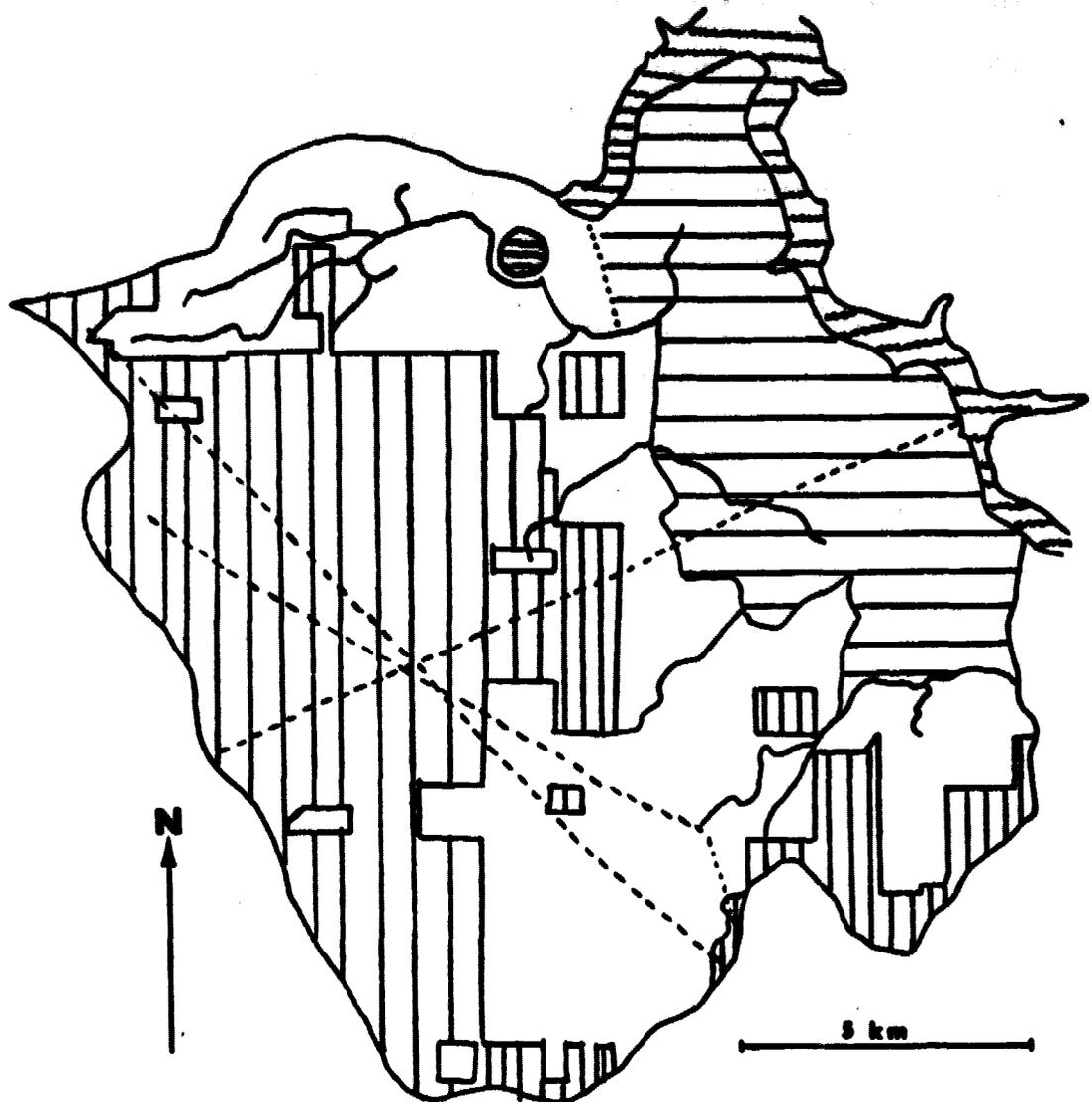
PLATFORM*	IMAGE ID #**	FRAME #	DATE	FILM/BAND (wavelength μm)	SCALE	STEREO
Aircraft	5730014610048	57, 58	9/19/73	BIR (.690 - .760)	1:438,000	Y
	5730014600048	57, 58	9/19/73	B&W (.580 - .680)	1:438,000	Y
	5730014590048	57, 58	9/19/73	B&W (.475 - .575)	1:438,000	Y
	5730014620048	56-58	9/19/73	CIR (.510 - .900)	1:438,000	Y
	5730014634508	4515-16	9/19/73	CIR (.510 - .900)	1:130,000	Y
	5720003080225	228, 229	4/27/72	BIR (.690 - .760)	1:420,000	P
	5720003070225	228, 229	4/27/72	B&W (.580 - .680)	1:420,000	P
	5730003060225	228, 229	4/27/72	B&W (.475 - .575)	1:420,000	P
	5720003090225	228, 229	4/27/72	CIR (.510 - .900)	1:420,000	Y
	6166001505383	90-92	5/17/71	NC NA	1:120,000	Y
SkyLab (ETC) (MSC)	C30B085342000	NA	9/10/73	B&W (.5 - .7)	1:950,000	N
	C30B087057000	NA	9/15/73	CIR (.5 - .88)	1:950,000	N
	C30A040313000	NA	9/15/73	NC (.4 - .7)	1:2,850,000	Y
	C30A039313000	NA	9/15/73	CIR (.5 - .88)	1:2,850,000	Y
	C30A038313000	NA	9/15/73	BIR (.8 - .9)	1:2,850,000	Y
	C30A037313000	NA	9/15/73	BIR (.7 - .8)	1:2,850,000	Y
	C30A041313000	NA	9/15/73	B&W (.6 - .7)	1:2,850,000	Y
	C30A042313000	NA	9/15/73	B&W (.5 - .6)	1:2,850,000	Y
Landsat (MSS Images)	8102815295500	NA	8/20/72	5,7 ⁶	1:3,369,000	N
	8124415305500	NA	3/24/73	5,7	1:3,369,000	N
	8144215282500	NA	10/8/73	5,7	1:3,369,000	N
	8548614393500	NA	8/17/76	4,5,6,7	1:3,369,000	N
	8276215033500	NA	2/22/77	5,7	1:3,369,000	N
	8281615010500	NA	4/17/77	5,7	1:3,369,000	N
	82108614482X0	NA	1/12/78	5	1:3,369,000	N
	83008315181X0	NA	5/27/78	5	1:3,369,000	N
	82124814563X0	NA	6/23/78	5,7	1:3,369,000	N
	83024515194X0	NA	11/5/78	5,7	1:3,369,000	N
	83029915193X0	NA	12/29/78	5	1:3,369,000	N
	8548614394500	NA	8/17/76	4,5,6,7	1:3,369,000	N
(MSS Tape) (RBV)	83008315181XA	NA	5/27/78	(.505 - .750)	1:1,684,000	N
	83010115182XA	NA	6/14/78	(.505 - .750)	1:1,684,000	N
	83029915192XC	NA	12/29/78	(.505 - .750)	1:1,684,000	N

Table 3: Remotely sensed data selected for clearcutting analysis (Legend on next page)

Table 3 Continued:

LEGEND

- * - see literature review for platform descriptions
- ** - From EROS computer listings
- φ - Landsat MSS wavelengths as follows
 - 4 - 0.5 - 0.6
 - 5 - 0.6 - 0.7
 - 6 - 0.7 - 0.8
 - 7 - 0.8 - 1.1
- ETC - Earth Terrain Camera
- MSC - Multispectral Camera
- MSS - Multispectral Scanner
- RBV - Return Beam Vidicon
- NA - not available
- BIR - black-and-white infrared
- B&W - black-and-white
- CIR - color infrared
- NC - natural color
- Y - Yes
- N - No
- P - Partial



KEY

-  - water
-  - private land (no cutting records available)
-  - neighboring ranger district (cutting records not obtained)
-  - Sheffield Ranger District (cutting records obtained)
-  - road
-  - pipeline
-  - separation between two areas

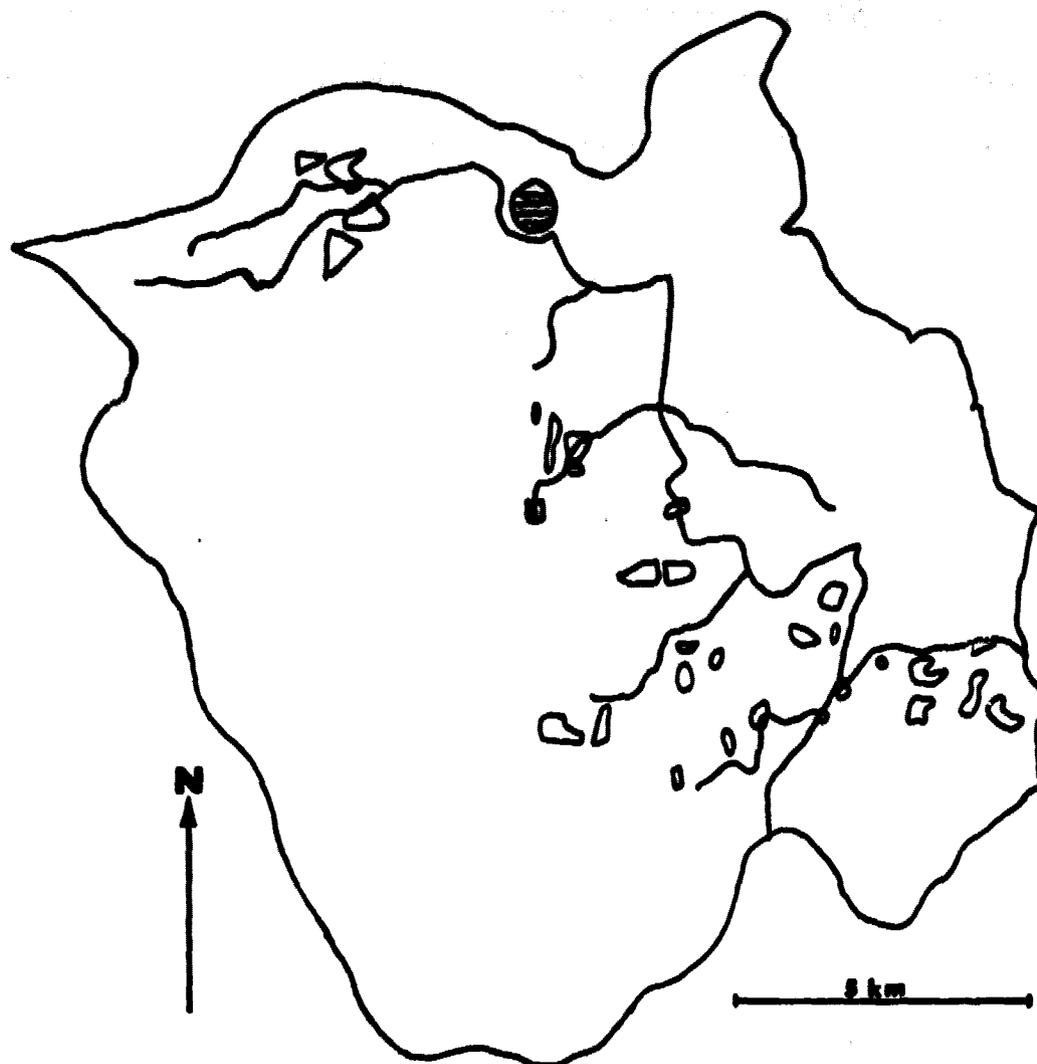
Figure 6: Master overlay of study site A.

in an area for which cutting records were available. From this original overlay, numerous "skeleton" overlays, showing only the site boundary, the pumped storage reservoir, and certain roads, were made for use as base maps for recording the location of areas identified as clearcut during the analysis of each of the photographs (Figure 7).

Each photo transparency was placed on the overhead projector and masked with cardboard strips in order to allow for more comfortable viewing of the images against the smooth white wall onto which they were projected. The photograph was secured and kept flat by placing a clean piece of glass over it.

The skeleton overlays were positioned over the projected images, using the roads for control where possible, since the water bodies in the area often did not produce good alignments, probably due to water level changes during different times of the year. Using the spatial and spectral indicators discussed earlier in this study, clearcut areas were tentatively identified and recorded on the overlays. This procedure was followed for all of the aircraft photographs at scales of 1:400,000 or smaller, and for the Skylab Earth Terrain Camera photographs. Only the three best Skylab Multispectral Camera photographs were analyzed in this way since the presence of cloud and the overall quality of the images made it difficult to distinguish clearcut areas even on the better film types. Overlays of the 1:120,000 and 1:130,000 scale aircraft photos were made at the original photo scale, since this was sufficient for accurate comparison with the ground data.

Each overlay resulting from the analysis of a photograph was compared to the Allegheny National Forest map containing the ground data. The number of clearcuts correctly identified was recorded



KEY

- ⊖ - water
- ⊖ - area identified as clearcut
- ⌞ - road

Figure 7: Skeleton overlay of study site A. Clearcuts recorded were identified on an enlargement of a black-and-white photo taken on September 19, 1973, at an original scale of approximately 1:438,000.

for each photo. Since the transfer of the ground data from the 1:15,840 scale compartment maps to the smaller scale base map was subject to some slight error in cut location, and since perfect alignment was difficult to achieve between the overlays and the enlarged photos; close alignment, and known shapes and distributions of clearcut were considered when deciding if an area was correctly identified as a clearcut.

As an estimate of accuracy, the number of classified cuts for each photo was compared to the known number of cuts present at that date and recorded as a percentage. Due to the sources of confusion regarding exact clearcut location mentioned in the preceding paragraph, it was the relative number, and not the absolute number of identified cuts that was considered when comparing the value of the various data sources examined. The resolution of the 1:130,000 CIR film was such that clearcuts could be distinguished from other land uses and therefore no areas were misclassified. After having compiled the ground data, and having examined the 1:130,000 scale CIR photos, the investigator's familiarity with the study area allowed him to avoid misclassification of non-clearcut areas. This accuracy comparison, as well as an assessment of the difficulty involved in identifying the clearcuts, was used to determine which films, scales, and seasons were best suited to the task of identifying clearcut areas.

During the time that the overlays were being generated, each photo was being qualitatively assessed in regard to its overall usefulness in yielding information about the presence or condition of revegetation on areas identified as clearcut.

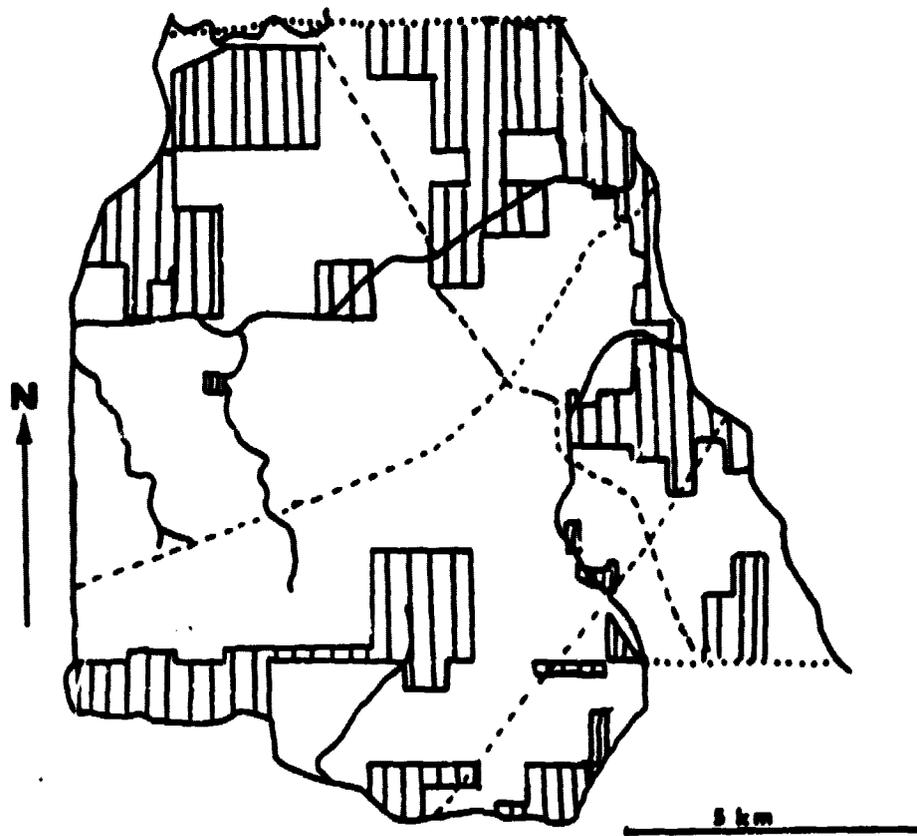
In order to determine the usefulness of stereoscopic analysis for the identification of clearcut areas and revegetation assessment, each photo for which stereoscopic coverage was available (see Table 3) was examined on a variable intensity light table using a variable magnifying stereoscope (zoom stereoscope).

Several methods of enlarging the photos for more detailed and convenient viewing were examined in order to determine their relative merits, using a microfiche reader, an overhead projector, a zoom stereoscope, a zoom transfer scope, and by rear-view projection.

3.5.2 Landsat Data

Landsat imagery from two sensors and in two formats was analyzed to see if clearcut areas could be identified and differentiated from other land uses on satellite imagery. Black & white 70mm transparencies of images acquired by the Multispectral Scanner (MSS) and the Landsat-3 Return Beam Vidicon (RBV) were visually examined using enlargement and color-additive viewing. A computer compatible tape (CCT) of an August 1976 Landsat scene was digitally analyzed to determine if any improvement in identifying clearcut areas could be accomplished over the visual analysis of the imagery.

Study site B was selected for the Landsat analyses over study site A because it provided a somewhat more diversified cutting history with respect to the dates and sizes of the cuts, and because it included several urban and agricultural areas not present in study area A. In Figure 8 is shown the master overlay of study area B,



KEY

-  - private lands (no cutting records available)
-  - Sheffield Ranger District (cutting records obtained)
-  - road
-  - pipeline
-  - non-road study site boundary

Figure 8: Master overlay of study site B.

including the site boundary, key roads and pipelines, and private lands for which no cutting records were available.

3.5.2.1 Visual Imagery Analysis

MSS band 5 and/or 7, 70mm transparencies were obtained for the region of interest during various seasons of the year. Study site B was photographically enlarged between 5 and 6 times to a scale of approximately 1:600,000. Blue sensitive masking film (Kodak 2136) was used to produce 10.2 x 12.7 cm (4 x 5 inches) enlarged black & white transparencies. The enlargements were of the opposite format (positive or negative) from the originals. Although not attempted in this study, the use of a lantern projector to enlarge the original 70 mm MSS and RBV transparencies to base map scale, might be used to eliminate the development of an intermediate photographic enlargement.

Each of the enlargements was examined on a light table using a magnifying glass to determine if clearcut areas could be identified on the images. It was also noted whether other items of interest, such as farm lands and small urban centers, could be distinguished from clearcut lands. Those images on which clearcutting could be identified were enlarged to a scale of approximately 1:125,000 using an overhead projector. Areas interpreted as clearcut were recorded on matte acetate overlays, on which the boundary of the study site had been previously drawn. The overlays developed for each date were compared to the base data as recorded on the Allegheny National Forest map. The number of known clearcuts correctly identified was determined using the

same considerations as used for the accuracy analysis of the photographic data sources.

Three Landsat-3 RBV images were enlarged between 5 and 6 times to a scale of approximately 1:300,000, in order to compare the usefulness of the imagery from this larger scale, single band sensor to the MSS imagery. These RBV enlargements were projected to base map scale and examined to determine the number of clearcuts correctly identified, in the same manner as described for the MSS imagery.

A color-additive viewer (CAV) was used with the MSS imagery in an attempt to enhance the separation between farmland or urban areas and clearcuts, between recent (occurring between two image dates) and older (before the earlier image date) clearcut areas, and between clearcuts of various levels of revegetation or ages. This enhancement is produced in the CAV by superimposing up to four images of the same area, taken at different times or in different spectral regions, onto the machines' common viewing surface. Each of the four images can be simultaneously illuminated with blue, green, red, or white light provided by movable filters within the CAV.

Color additive viewing was first attempted using the original 70mm transparencies; however, it was found that at this scale even minute errors in alignment and slight image blur were enough to create indistinct tonal signatures that were not sufficient to separate categories of interest from each other. Several of the 10.2 x 12.7 cm enlarged transparencies were therefore cut into 70mm chips which were mounted in the CAV.

Winter and summer, positive and negative images, some separated by up to four years, were used to enhance the presence of new verses old cuts and to differentiate between levels of revegetation. Images from different bands, acquired on the same date, were also used to examine levels of revegetation. A spring scene was used in combination with the summer and winter scenes to aid in distinguishing between agricultural land and clearcut areas. Those image and filter combinations that yielded the most satisfactory results were photographed using a 35mm camera and Kodak Tungsten 160 Ektachrome film.

Results similar to those obtained through color-additive viewing should be obtainable by color enhancement of the MSS images using diazo foils. This is a subtractive-color enhancement procedure in which yellow, magenta, and cyan transparencies, contact duplicated from black and white images of different bands or dates, are overlaid onto each other on a light table in order to accentuate the detectability of a feature of interest (Hardy et al, 1975). This technique has the advantage of being less expensive than color-additive viewing.

3.5.2.2 Digital Analysis

Digital image analysis refers to the computer aided interpretation and classification of the actual numerical reflectance values recorded by a scanner, on a pixel-by-pixel basis. The data are originally collected on magnetic tape from which a computer compatible tape (CCT) is produced for user analysis. Maximum spatial resolution and spectral sensitivity are normally afforded through digital analysis, since the value for each pixel representing a ground area of slightly

less than 0.5 hectares, is individually examined, rather than being visually interpreted as part of a group of similar pixels. Both interactive and non-interactive computing systems have been developed to perform digital analysis of digitized remotely sensed data.

Interactive systems allow the operator to have real-time control over the operations being performed by the computer, since he is able to observe the progression of results on a video screen, and alter his decisions based on the results of his prior actions. Using an interactive system, an operator can select training sites, generate statistics, develop class signatures, and classify an area of interest within a matter of minutes.

Non-interactive systems can perform essentially the same functions as interactive systems. They can be programmed into existing computing facilities, but have the disadvantages of requiring a greater turn-around time, not allowing the operator to alter his analysis until the completion of a routine, and providing only paper printouts, rather than images.

Based upon the apparent preference of previous investigators to use summer ("leaf-on") imagery for clearcut monitoring, the CCT of a Landsat scene taken over the study area on August 17, 1976, was selected for analysis. This selection was based upon the scene's favorable season, image quality, and cloud-free nature. The digital analysis was performed noninteractively using the ORSER program (Borden et al., 1977), modified for use on the Cornell University IBM 370/168 computer. The location of study site B was identified, and a subset data tape was

constructed for this area in order to reduce computation costs and increase processing efficiency.

Although the review of the literature seemed to discourage its use, an initial attempt was made at classifying the land use categories in the study area using an unsupervised classification routine. In this procedure the computer independently computed spectral signatures using a clustering algorithm and developed a map symbolically representing pixels by the cluster to which they were assigned. The map was compared against ground data in order to determine what land uses if any were being consistently depicted by a given signature and symbol. No relationship between the map and the ground data could be detected, and although continued trials using varied limits and sampling intensities may have produced acceptable classification results, it was considered unlikely, and a supervised classification was attempted.

The initial step in the supervised classification was the generation of a brightness map for each of the four Landsat spectral bands to be used for locating training areas. Ground data, the 1973 high altitude photos, and August 17, 1976 Landsat images were used to identify training areas for the following classes: clearcut forest, farm, urban, and forest. Examination of the brightness maps showed band 5 to most clearly depict the categories of interest, and it was therefore used to acquire the coordinates for the training areas.

Statistical data, in the form of reflectance values and standard deviations for the four Landsat bands, needed to develop classification signatures, were obtained for all of the training areas. The statistics for each land use were examined and averaged to obtain a spectral classification signature for each category of interest.

Using a nearest neighbor classification routine, and the classification signatures developed, a map of study area B was generated in which the entire area was classified as "clearcut," "farm," "urban," "forest," and "other." Various limits were tried in order to achieve the best possible classification.

In an attempt to improve the accuracy of the classification, a canonical analysis was performed on the statistics generated for the land uses of interest, and the results were then used in the classification of the study site.

3.6 Field Investigation

The study area was first visited on the 24th of March, 1980. The purpose of this visit was to meet with personnel of the Sheffield Ranger District in order to determine the availability of suitable ground data in the form of forest harvesting records, to acquire the cutting records available, and to discuss general questions pertaining to the forests and forestry of the area. In order to become familiar with local ground conditions and the appearance of clearcuts during the nongrowing season, several cuts in study area A were investigated. Weather conditions were such that only a few inches of melting snow were present on the ground.

The study area was again visited on the 3rd and 4th of June, 1980, after analysis of the remotely sensed data had been completed. A meeting was again held between the author and Sheffield personnel to discuss questions that had arisen during the analysis of the imagery. Several cuts of different ages and sizes in study area A were visited

to determine their appearance with full foilage. Study area B, which was not visited during the first trip, was examined with respect to the appearance of clearcuts and other areas, such as agricultural lands that were confused with clearcuts. Sites of particular interest were investigated.

4. RESULTS

4.1 Analysis of Aircraft Photography

Small scale aerial photography was found to be well suited for both the identification of clearcut lands and for the general assessment of revegetation status.

The season during which photography is acquired seems to be the major factor affecting one's ability to identify clearcuts on aerial photography. Photographs acquired at times when there was no leaf cover proved to be of virtually no value, especially when compared with photos taken during the growing season, regardless of scale. Natural color photos, at a scale of 1:120,000 taken in the spring before leaves were present on the trees, showed fewer clearcuts than photos taken at a scale of 1:438,000 in the summer. Black and white summer photos were superior to color infrared photos taken when no leaf cover was present. As scale decreased, the seasonal effect became more pronounced. Shown in Figure 9 are two B&W and two CIR photos, one each from spring, before leaf, and from a full foliage period in September. The figure illustrates the effect of season on aerial photography's usefulness for clearcut identification.

The preferred film type at all scales, especially if information on revegetation is desired, is color infrared. This film allowed for the best differentiation of clearcuts from their surroundings, and of

variations of revegetation levels within and among cuts. A comparison of Figure 9 I and III, and II and IV, illustrates the effect of film type on aerial photography's usefulness for clearcut monitoring.

Figure 10 is a stereoscopic pair of a portion of the 1:130,000 CIR photos taken in September 1973. It illustrates what may be considered the maximum amount of information obtainable from small scale imagery, since it combines the best season, film type, and scale, while providing for stereoscopic viewing.

Cuts just slightly larger than 1 hectare and 7 years old could be identified on summer B&W, BIR, and CIR photos with original scales of 1:438,000 when enlarged to approximately 1:125,000 (Figure 9 I and III, G). Alignment of the photos to the base map was somewhat more difficult using summer photos, because smaller forest roads were obscured by the surrounding forest canopy.

Clearcut areas were identified by their lighter tone on B&W photos (Figure 9 III), and by their generally lighter, but sometimes darker, appearance on BIR photos. On CIR photos recent cuts appeared whitish to blue-gray, while areas that had revegetation present were a pink to light red, and had a smoother texture than the surrounding forest (Figure 10). Forest areas are a medium gray on B&W and BIR summer photos (Figure 9 III), while they appear deep bright red on CIR photos (Figure 9 I). The linear character of the cut boundary, sometimes enhanced by the shadow cast into the cut by the surrounding trees, was also very useful in distinguishing clearcuts from their surroundings. Adjacent cuts that were made several years apart were easily identified as such on CIR photos (Figure 10, C).

Figure 9:

Comparison of film types and season for identifying clear-cutting and revegetation. Clearcuts at A are clearly visible on summer photos (I & III) and are discernible on spring photos (II & IV), while cuts at B, though clearly visible in the summer, cannot be seen in the spring. Farmed areas are clearly visible at all times (C). Certain clearcuts are more difficult to identify on the black-and-white photos than on the color infrared photos (D). While bare soil from recent cuts (F) can be easily differentiated from revegetation (E) on color infrared photos, these features appear somewhat similar on the black-and-white photos. A 7 year old, 3 acre clearcut is visible on the summer photo at G.

I - CIR photo taken Sept. 19, 1973; original scale approximately 1:438,000 (frame 57, NASA): II - CIR photo taken April 27, 1972; original scale approximately 1:420,000 (frame 228, NASA): III - B&W photo taken Sept. 19, 1973; original scale approximately 1:438,000 (frame 57, NASA): IV - B&W photo taken April 27, 1972; original scale approximately 1:420,000 (frame 228, NASA). Illustrations approximately 3.5 times original scale.

Figure 9 I & II

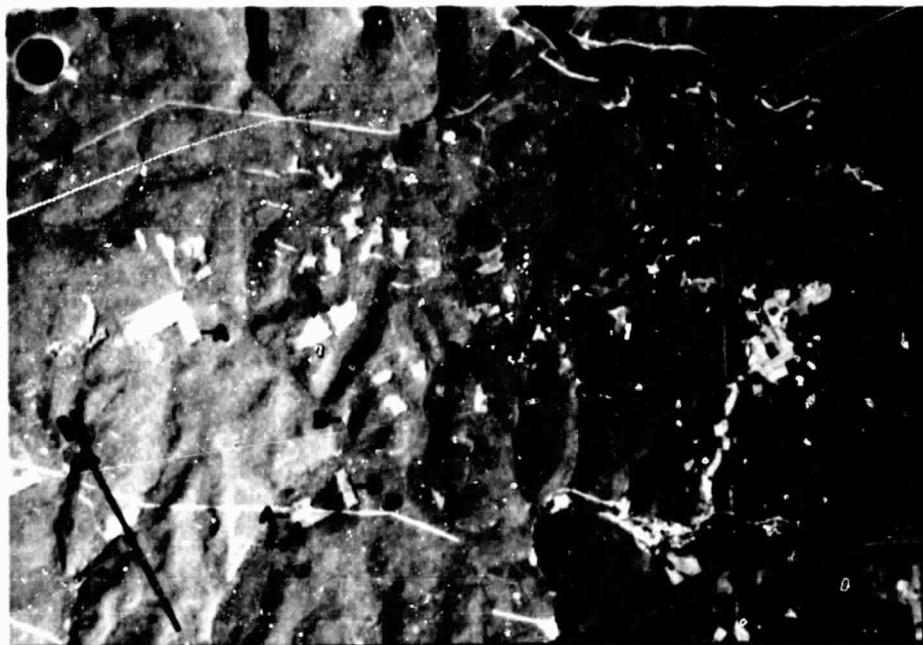
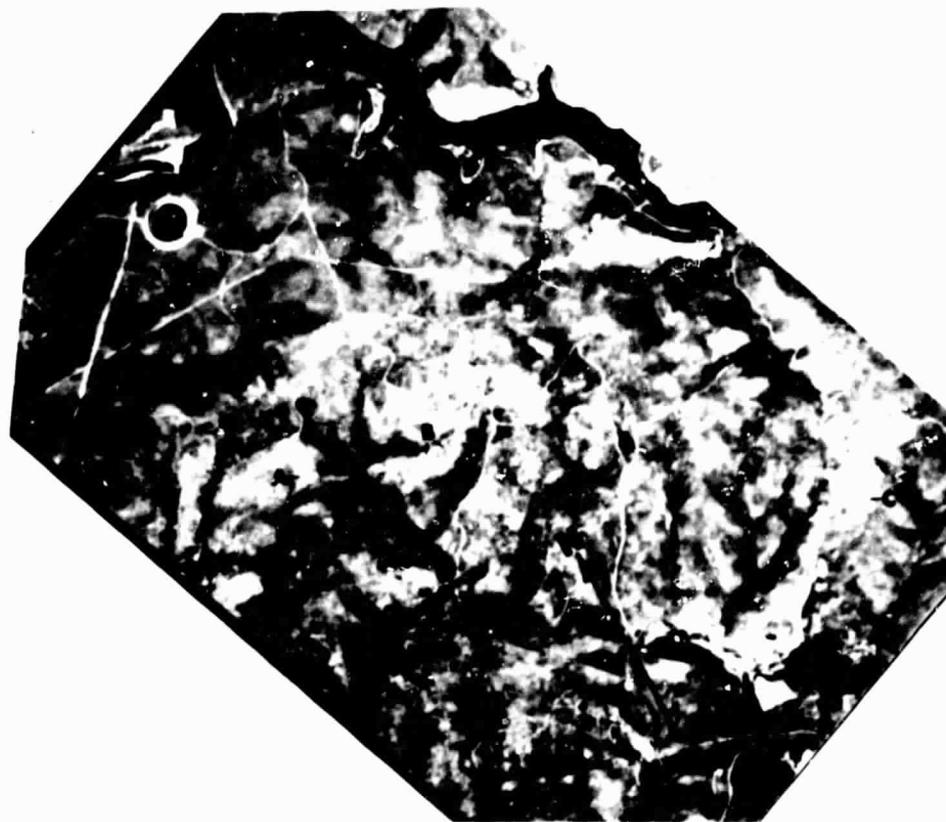
I - Summer Color InfraredII - Spring Color InfraredORIGINAL PAGE IS
OF POOR QUALITY

Figure 9 III & IV

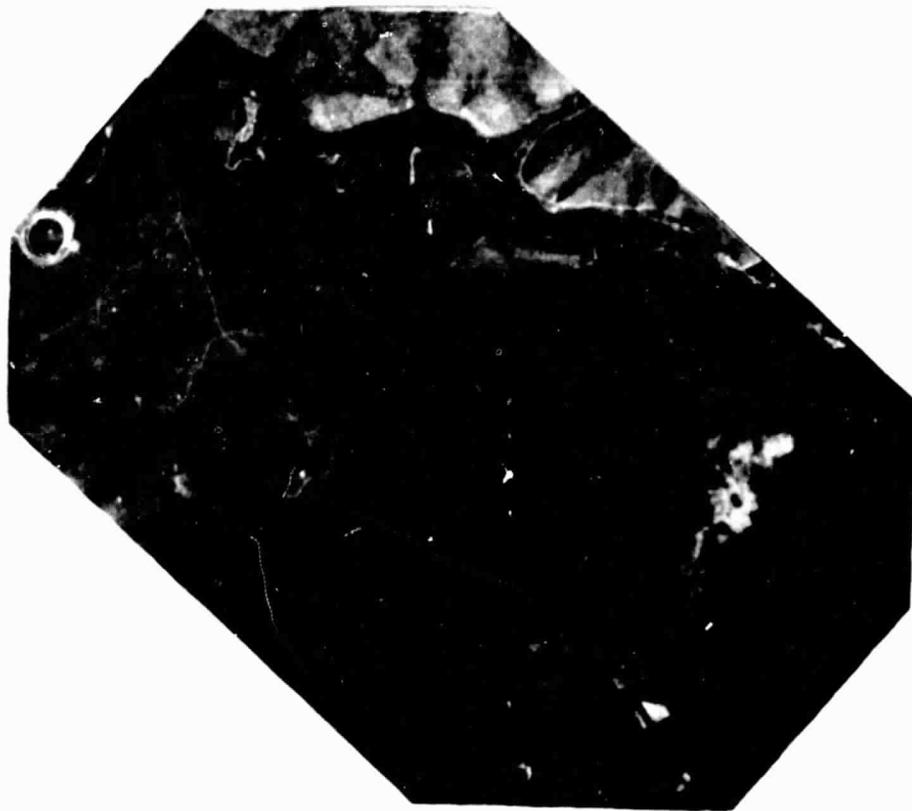
III - Summer Black-and-WhiteIV - Spring Black-and-White



Figure 10: Color infrared (CIR) stereogram of a portion of study area A. The illustration shows the usefulness of CIR photography and stereo viewing for clearcut identification and revegetation assessment. One or two year old clearcuts appear gray or blue gray (A), while older, revegetated cuts are pink or reddish (B). Revegetated cuts are not as red as the surrounding forest (H) and have a somewhat smoother texture. Adjacent clearcuts, of different ages, can be differentiated by noting the revegetation present in the older portions (C). Differences in revegetation of cuts of the same age can be observed. D and E were cut in the same year; however, D shows little sign of revegetation. A partial cut can be identified at F, while a 7 year old, 3 acre cut appears at G. Comparison with Figure 9 I shows that the features described here are observable on that photo whose original scale was 1:438,000. Stereo viewing gives topographic information, as well as rough relative height estimates of revegetation at magnified scales. Taken from Sept. 19, 1973 CIR transparencies; original scale approximately 1:130,000 (frame 4515 & 4516, NASA). Illustration at approximately original scale.

ORIGINAL PAGE IS
OF POOR QUALITY

Summer CIR photos at a scale of approximately 1:130,000 allowed for the identification of 100 percent of the known clearcuts in the study area (Table 4). The assessment of photography taken the same day at 1:438,000 showed that, at this scale and season, 82 to 97 percent of the clearcuts could be identified using various films. In contrast, the best result obtained in the nongrowing season at the 1:420,000 scale was 15 percent using CIR photos.

Listed in Table 4 are the accuracy results of clearcut identification for aerial and space photography and for enlargement viewing of Landsat B&W images. Accuracies are recorded as a percentage of the total number of clearcuts known to exist in the study area. It is important to recall two characteristics of the accuracy counts: (1) because there is some amount of subjectivity in the identification of the cuts, relative and not absolute percentages should be compared; and (2) no indication of the number of misclassified areas is given because the investigator became familiar with the study area as a result of the compilation of ground data and analysis of the 1:130,000 scale photos. This familiarity made it possible to prevent areas that appeared similar to clearcuts at scales smaller than 1:130,000 from being classified as such.

The procedure of identifying clearcuts on the photos, enlarged to 1:125,000 and recording the results on overlays to the base map was done twice, with several weeks between trials. Comparison of the overlays of each photo indicated that identification accuracy estimates did not differ by more than 10 percent for any given comparison, and were within 3 percent on the average.

Table 4: Comparative summary of the accuracy of clearcut identification using various types of small scale remotely sensed data.

PLATFORM	DATE	FILM/BAND (wavelength μm)	SCALE	% ACCURACY OF CLEARCUT IDENTIFICATION
Aircraft	9/19/73	BIR (.690 - .760)	1:438,000	95
	9/19/73	B&W (.580 - .680)	1:438,000	82
	9/19/73	B&W (.475 - .575)	1:438,000	87
	9/19/73	CIR (.510 - .900)	1:438,000	97
	9/19/73	CIR (.510 - .900)	1:130,000	100
	4/27/72	BIR (.690 - .760)	1:420,000	0
	4/27/72	B&W (.580 - .680)	1:420,000	12
	4/27/72	B&W (.475 - .575)	1:420,000	9
	4/27/72	CIR (.510 - .900)	1:420,000	15
	5/17/71	NC (unavailable)	1:120,000	50
Skylab (ETC)	9/10/73	B&W (.5 - .7)	1:950,000	100
	9/15/73	CIR (.5 - .88)	1:950,000	89*
	(MSC) 9/15/73	CIR (.5 - .88)	1:2,850,000	29*
	9/15/73	NC (.4 - .7)	1:2,850,000	29*
	9/15/73	B&W (.5 - .6)	1:2,850,000	0*
Landsat (MSS)	8/20/73	5 (.6 - .7)	1:3,369,000	40
	8/17/76	5 (.6 - .7)	1:3,369,000	38
	2/22/77	5 (.6 - .7)	1:3,369,000	82
	1/12/78	5 (.6 - .7)	1:3,369,000	68
	5/27/78	5 (.6 - .7)	1:3,369,000	46
	6/23/78	5 (.6 - .7)	1:3,369,000	49*
	12/29/78	5 (.6 - .7)	1:3,369,000	72
	(RBV) 5/27/78	(.505 - .750)	1:1,684,000	66
	6/14/78	(.505 - .750)	1:1,684,000	62*
	12/29/78	(.505 - .750)	1:1,684,000	77

LEGEND: ETC - Earth Terrain Camera; MSC - Multispectral Camera;
MSS - Multispectral Scanner; RBV - Return Beam Vidicon Camera;
BIR - black-and-white infrared; B&W - black-and-white;
CIR - color infrared; NC - natural color; * - study area partially
obscured by clouds

4.2 Analysis of Skylab Photography

The usefulness of Skylab photography for clearcut identification and monitoring ranged from excellent to very poor.

Photographs acquired in late summer using the Earth Terrain Camera (ETC) were excellent. An accuracy count of the clearcuts identified on the B&W photo negative resulted in 100 percent identification, while 97 percent were identified on the positive of the same photo. Analysis of the negative was somewhat easier because the dark areas, representing the clearcuts, stood out as if already outlined against the lighter background of the forested areas (Figure 11). It was possible to identify 89 percent of the cuts in the study area on a CIR ETC photo, even though there was a significant amount of cloud cover present (Table 4). With enlargement, it was possible to distinguish varying amounts of revegetation within and among the various clearcuts identified on the CIR photo. This was possible to some extent on the B&W photo, where more recent or poorly revegetated cuts were darker than the older cuts present (Figure 11, A and B).

The photographs provided by the Multispectral Camera (MSC) yielded generally poor results in clearcut identification. A large amount of cloud cover may have been somewhat responsible for this in some cases, but it also appeared to be a result of scale and film spectral sensitivity. The study area could easily be identified on the two BIR photos because of the proximity of the Allegheny Reservoir; however, no identification of clearcuts was possible even when enlarged to a scale of approximately 1:125,000. Due to their uniform tone, it took several minutes simply to identify the study area on the B&W photos. Some slight tonal variations were visible, but were often too indistinct to be conclusively mapped as

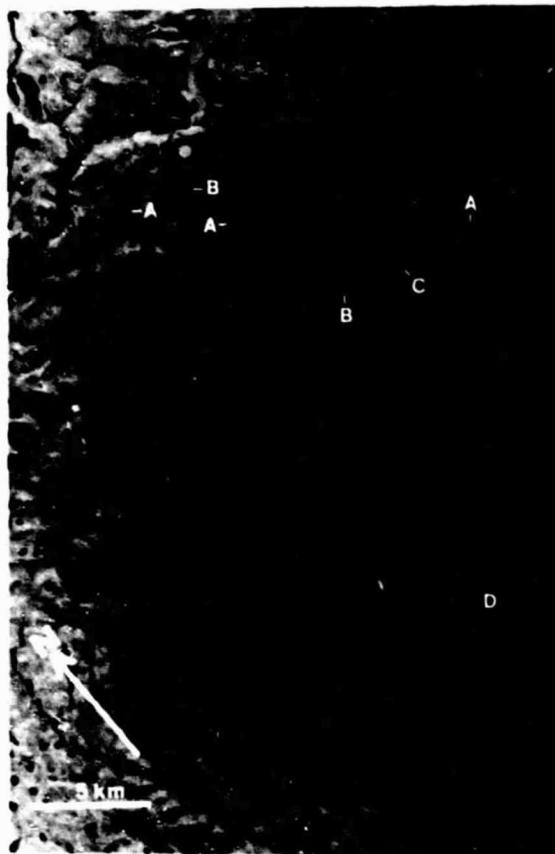


Figure 11: Skylab Earth Terrain Camera, Black-and-White negative of study areas A and B. Clearcuts appear as gray to black spots against the lighter background of the surrounding forest. Recent or poorly revegetated clearcuts are dark (A), while those that have been revegetated are lighter (B). A 7 year old, 3 acre cut can be seen at C, and strip clearcutting is present at D. Taken Sept. 10, 1973; original scale approximately 1:950,000. Illustration approximately 3 times original scale.

clearcut areas. The natural color and CIR photos were the best for clearcut identification, allowing the identification of approximately 30 percent of the cuts in the study area (Figure 12). The accuracy assessment must be considered as an underestimate of the true usefulness of these two films. More cuts would have been detected if the area had not been largely cloud covered. The production of an intermediate photographically enlarged product may have aided in clearcut identification since the greater than 20x enlargement produced by the overhead viewer was somewhat less sharp than the approximately 10x or less overhead enlargement of the other data types. Cut boundaries were often difficult to distinguish, thereby making plotting of the cuts difficult. Some degree of revegetation could be detected on the CIR photos. The results of accuracy counts performed on the Skylab photography are shown in Table 4.

4.3 Analysis of Landsat Imagery

4.3.1 Black and White Image Analysis

The percentage of the clearcuts known to exist in the study area identified through photo-interpretation of enlarged B&W images are listed in Table 4. Using MSS images, it was possible to identify an average of 43 percent of the clearcuts on the images acquired during the growing season, as compared to an average of 74 percent on images taken at times when snow cover was present. The use of RBV images increased the number of cuts that could be identified on summer images more so than on winter images: an average of 43% (MSS) to 64% (RBV) for summer versus 72% (MSS) to 77% (RBV) for winter. For RBV images, the season of acquisition

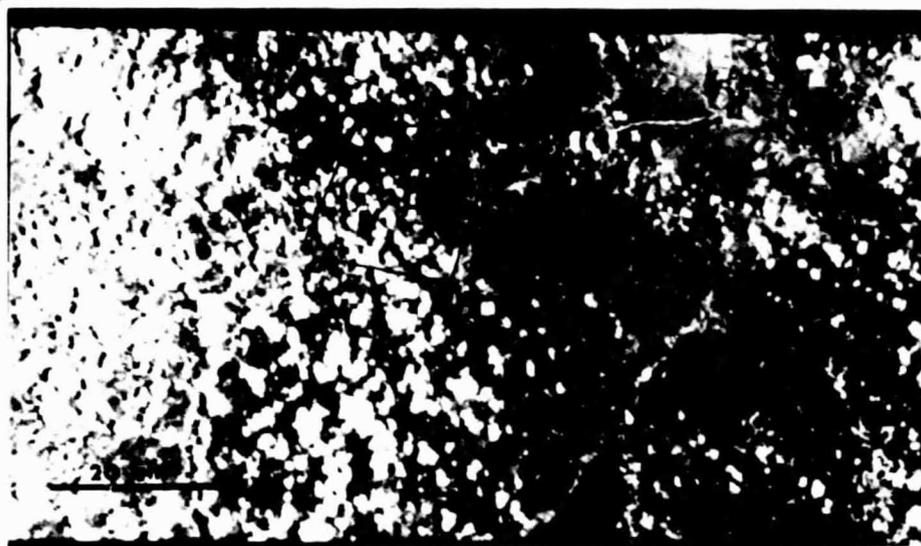


Figure 12: Skylab Multispectral Camera color infrared photograph of the study area. Recent clearcuts at R can be detected by their bluish color, seen between clouds at C. Resolution restrictions make it difficult to accurately identify older and smaller clearcuts, such as those within the small box labeled O. Taken Sept. 15, 1973 at an original scale of approximately 1:2,850,000. Illustration approximately 3.5 times original scale.

ORIGINAL PAGE IS
OF POOR QUALITY

therefore seems less important than for MSS images because the greater resolution allowed for the detection of more clearcuts in summer when they are less distinct from the surrounding forest. Image analysis and overlay production was done two times with approximately one month between trials. A comparison of the overlays indicated that the accuracy of clearcut identification averaged within 5 percent on the two trials and did not exceed 10 percent for any pair of overlays compared.

It was found that seasonal effects played a crucial role in determining the usefulness of Landsat imagery for clearcut identification. Band 5 images were used in the identification and mapping of clearcut locations. Summer images acquired in this band were found to be superior to images from band 7, on which virtually no clearcuts could be identified. For winter images, bands 5 and 7 seemed equivalent in the amount of information that could be extracted from them.

Images acquired during periods when there was no leaf cover or snow cover provided virtually no useful information on the location of clearcuts. Larger and more recent cuts were easily identified on images taken at times of full leaf cover; however, smaller and older cuts were more difficult to distinguish from the surrounding forest. It appears that early summer images allow for easier clearcut identification than those taken later in the summer because there is a greater spectral contrast between cut and uncut forests at that time.

Images acquired when there is snow on the ground can be used to identify clearcuts, including many of the smaller and older cuts that are more difficult to observe in the summer. Clearcuts as small as 2 hectares

and 10 years old could be detected on enlarged Landsat MSS B&W images taken when a snow cover was present (Figure 13 I, A). Figure 13 illustrates the comparison of summer and winter MSS images.

On all Landsat images, it is significantly more difficult to differentiate between clearcuts and other land uses, than it is on aerial or space photography due to Landsat's poorer resolution capabilities. Variations in terrain illumination due to topography, accentuated by lower sun angles in winter, results in some added confusion at that time (Figure 13 I). Clearcuts appear as lighter toned areas in both winter and summer images.

The mapping of clearcuts was relatively easy when the 5x photographic enlargement was further enlarged to the 1:125,000 base map scale using an overhead projector. Little information on revegetation could be derived from this analysis except through a comparison of detectability of clearcuts on winter and summer images. Cuts visible in winter but not in summer may be sufficiently revegetated to appear similar to the surrounding forest in the summer but be bare enough that there is little interference with reflection from snow in the winter.

Analysis of RBV images indicates that clearcuts can be identified using this sensor, both in the winter and the summer. Comparing an RBV and an MSS band 5 image acquired on the same overpass shows that the RBV's higher resolution and larger scale is useful in identifying, with greater certainty, the existence of smaller clearcuts. Cut boundaries are generally more distinct in the RBV images than in the MSS images. Figure 14 illustrates the comparison of MSS band 5 and RBV images.

Figure 13:

Comparison of winter and summer Landsat band 5 multispectral camera images. Small clearcuts were more easily seen on images acquired when a snow cover was present (IA), than on images acquired during the growing season (IIA). Clearcuts were often not differentiable from other land uses. The clearcut at D cannot be distinguished from the farm pasture at E. The revegetation of a site may be assessed by comparing its visibility on winter and summer images. Revegetation at C seems less complete than at B. The new cut at G may be mistaken for an older revegetated cut unless prior records are available. The lighter areas at F are a result of differential illumination and reflectance due to topography.

I - Taken Feb. 22, 1977: II - Taken August 17, 1976: Original scales approximately 1:3,369,000. Illustrations approximately 15 times original scale.

II - Summer



Figure 13 I & II

I - Winter

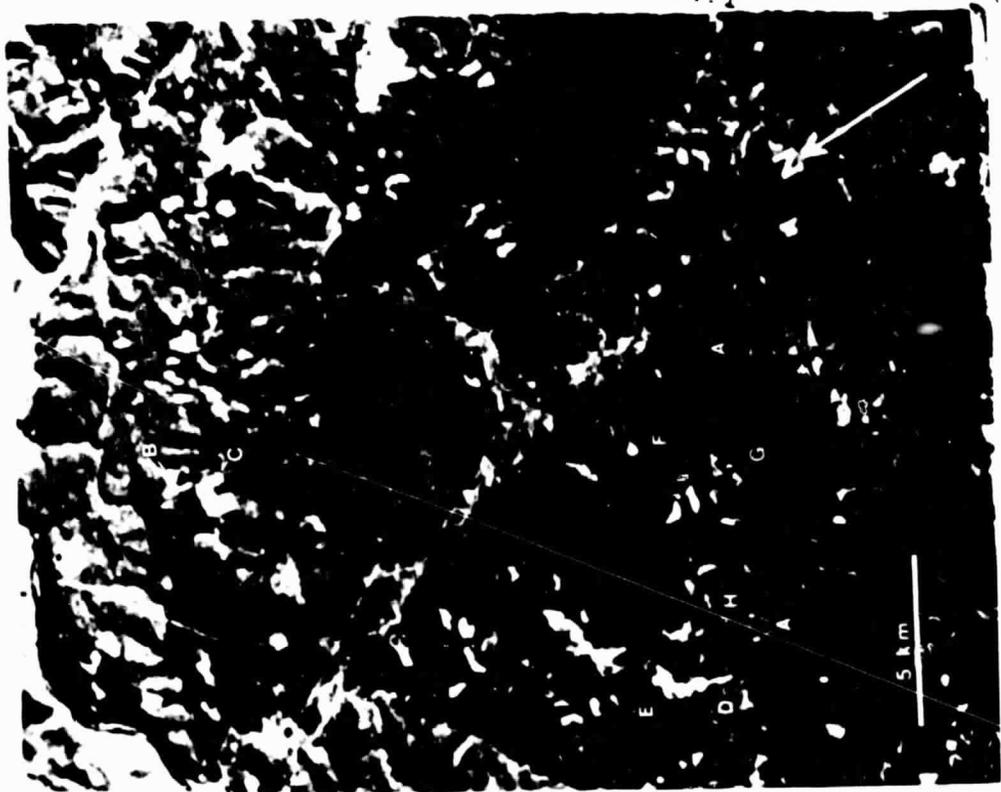


Figure 14:

Comparison of Landsat Multispectral Scanner (MSS) band 5 and Return Beam Vidicon (RBV) imagery. RBV images allow for the identification of smaller clearcuts, such as those at A. Boundaries are more distinct on the RBV images (B). The larger scale and better resolution of the RBV does not relieve the problem of confusing land uses, as can be seen by the comparison of the farmed area at C and the clearcut at D.

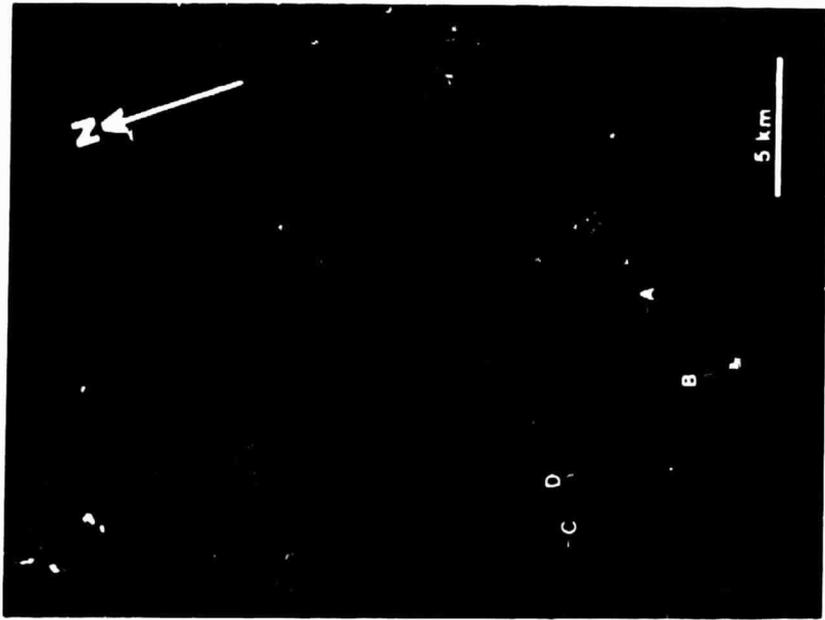
Taken May 27, 1978. I - Original scale approximately 1:3,369,000, Illustration approximately 15 times original scale. II - Original scale approximately 1:1,684,000, Illustration approximately 5 times original scale.

Figure 14 I & II

I - MSC



II - RBV



Although no counts were made of misclassified areas, it appeared that more areas would be misclassified on winter images than on summer images had prior knowledge of the area not been possessed by the investigator. It was determined through photo interpretation that the misclassified areas were often illuminated topographic features. Prior knowledge of the area prevented the misclassification of several areas that appeared similar to clearcuts. Certain known clearcuts were not identifiable because they could not be distinguished from other adjacent land uses.

4.3.2 Color-Additive Viewing

Color-additive viewing of the original 1:3,369,000, 70 mm MSS images proved to be of little value. The scale of the image produced on the viewing surface of the color-additive viewer (approximately 1:1,000,000) was such that it was difficult to obtain sufficiently precise alignment and to create unique and discernible color signatures for characteristics of interest, i.e., levels of revegetation, farmland versus clearcuts, and older versus recent clearcutting. The results using the 5x enlarged transparencies were much more favorable and the enlargements were therefore used for analysis. Using the enlargements, the scale of the image displayed on the CAV screen was approximately 1:200,000 and desired features could be more clearly observed.

Combining images taken on the same date in different bands, and combining images taken on different dates, both yielded valuable information. By combining bands 5 and 7 for one summer scene, it was possible

to distinguish roughly different age categories of cuts and general levels of revegetation. The amount of revegetation was assumed to be generally related to the amount of time elapsed since cutting, although it is known that it is possible for regeneration to decrease over time as a result of grazing by deer.

Shown in Figure 15 are the differences in appearance of clearcuts of various ages that can be detected using different Landsat bands from the same date. The combining of images taken several years apart allows for the easy differentiation of clearcutting that occurred in the time between the two image dates; however, older cuts are not differentiated from farmlands (Figure 16). If a spring image is included in the combination of multi-date images, it becomes possible to differentiate the older cuts from the farmlands because of the unique tone of the farms on the spring image (Figure 17). Information on the age of cuts could be obtained by successive mapping efforts; however, the capacity to distinguish between farmland and clearcuts would not be available without the use of a color-additive viewer.

4.3.3 Digital Image Analysis

The results of the digital analysis of the August 17, 1976 Landsat MSS scene indicated that this technique yielded inaccurate classification of clearcut lands. The procedure also is costly (\$200/tape + computer time) and time consuming. Variations in clearcut cover condition, the presence of land uses with similar spectral responses in the wavelengths being sensed, and illumination effects from topographic relief were contributing factors to the difficulty of digital identification and classification of clearcuts.

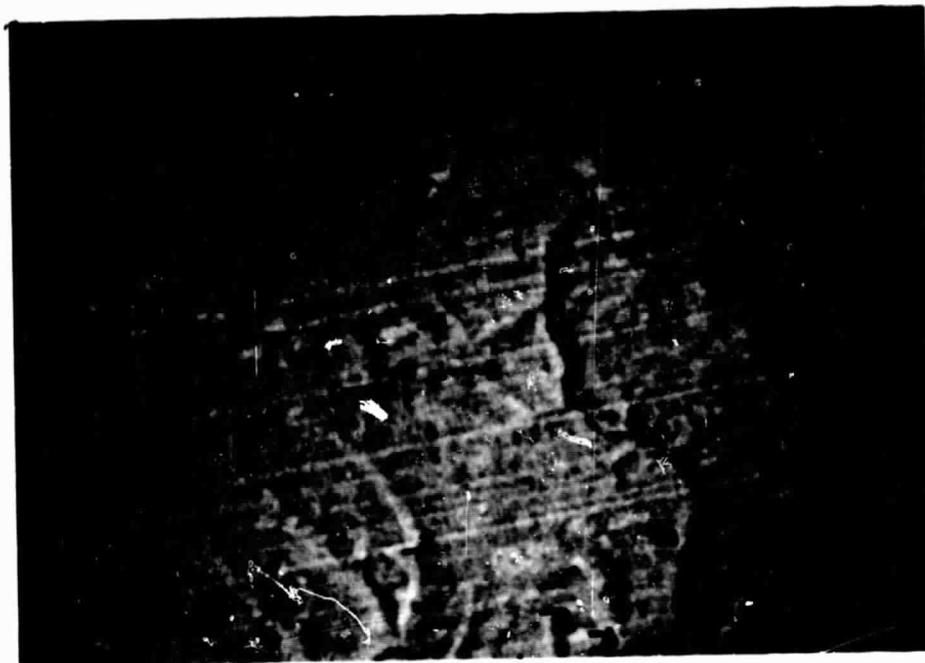


Figure 15: Appearance of clearcuts of different ages resulting from color-additive viewing of same date Landsat MSS images. Illustration is a combination of August 17, 1976 band 5 positive projected with red light, and a band 7 positive projected with green. In general, the most recent cuts have the greatest component of red in them. The areas at F and D were cut in 1975 and 1976 respectively. Areas E and C, cut in 1973 and 1974 respectively, show a greater component of pale orange combined with red, than the more recent cuts. Still older cuts at B, harvested in 1969, are mostly pale orange, while cuts at A, made in 1966, have lost most of their orange color, and appear a somewhat lighter gray-green than their surroundings. Farmland at G cannot be distinguished from the clearcut at H. Original image scale approximately 1:3,369,000, projected to approximately 1:200,000 for analysis. Illustration enlarged to approximately 1.5 times projected scale.

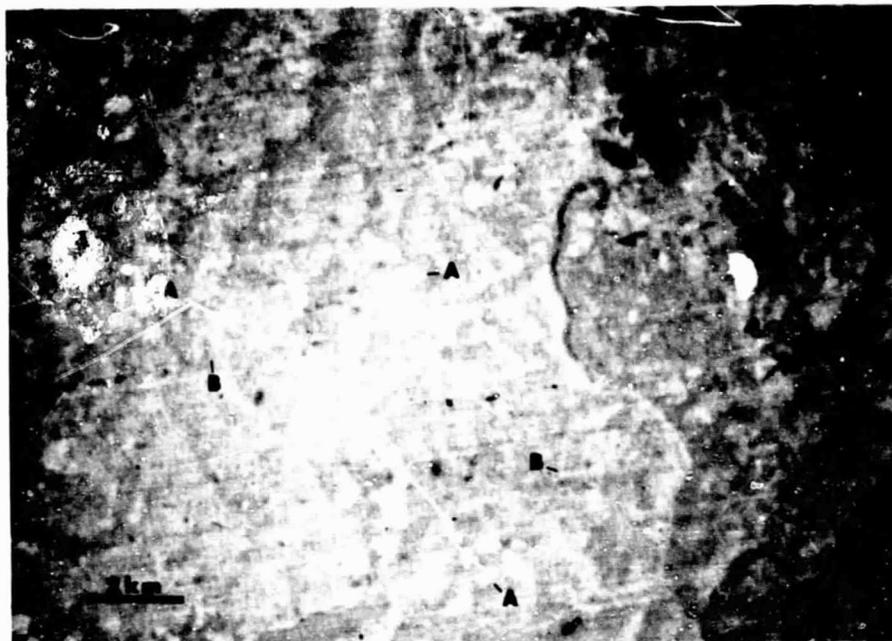


Figure 16: Separation of recent and older clearcuts through color-additive viewing of multi-date images. Illustration is of an August 20, 1972 band 5 negative projected with blue light, and a February 22, 1977 band 5 positive projected with red light. The light pink areas at A were clearcut in the time that elapsed between the image dates. Areas cut before the earlier image date appear red (B). The farmland at C could be differentiated from the recent cuts at A, but not the older cuts at B. D is an area of cloud and cloud shadow. Original image scale approximately 1:3,369,000, projected to 1:200,000 for analysis. Illustration enlarged to approximately 1.5 times projected scale.

ORIGINAL PAGE IS
OF POOR QUALITY



Figure 17: Separation of clearcuts and farmland through color-additive viewing of multi-date images. Illustration is of an August 20, 1972 band 5 negative projected with green light, a February 22, 1977 band 5 positive projected in blue, and a March 24, 1973 band 7 positive projected in red. The pink color of the farmlands at A can be easily differentiated from both the light blue recent clearcuts at B, and the older cuts at C. Cloud and cloud shadow occur at D. Original image scale approximately 1:3,369,000, projected to 1:200,000 for analysis. Illustration enlarged to approximately 1.5 times projected scale.

An attempt at classifying the study sites using an unsupervised classification scheme was unsuccessful. Although further refinements could have been attempted, the similarity of reflectance values of the classes of interest, the extremely poor results of the initial trial, and the lack of success reported by earlier researchers caused the author to devote his attention to supervised classification.

In order to select training sites for the supervised classification, brightness maps for all four bands were developed. It was found that clearcuts could be most clearly distinguished from forests on the band 5 brightness map. Prior knowledge of the area was needed to distinguish the clearcuts from farmlands and small urban areas which had nearly the same spectral reflectance as the clearcuts. Signatures were developed for the classes "clearcut," "forest," "urban," and "farmland" by averaging the reflectance values obtained from several training sites for each class in each of the four spectral bands.

When portions of the study area were classified using these signatures, many areas were misclassified. In general, the problem resulted from the similarity of spectral signatures among most of the classes of interest. Slight variations in reflectance over small areas caused most clearcuts to be classified as a conglomeration of symbols representing clearcuts, urban areas, farms, and other. Applying a canonical analysis, and using the results to classify the area, did little to improve classification.

4.4 Comparative Summaries

4.4.1 Suitability of Imagery Comparison

The suitability of various films and sensors, scales, and seasons for the identification of clearcutting and the assessment of revegetation is compared in Table 5. Revegetation in the table refers to the establishment of plants of any type on a clearcut piece of land, as opposed to regeneration which implies the establishment of trees similar to those removed or of other desirable species. The reason for the use of the less specific term is that species identification is virtually impossible at the small scales being examined.

4.4.2 Value of Stereoscopic Analysis

The remotely sensed data were viewed stereoscopically using a variable magnification (zoom) stereoscope which enabled stereo viewing at scales of 2.5 to 10 times those of the originals.

Only for the larger scale imagery did stereoscopic viewing provide significant information in addition to that obtainable through monoscopic analysis of enlarged imagery. Judgments of the approximate height of revegetation could be made using the 1:130,000 summer CIR photographs (Figure 10). This was done best at an enlargement of 10x.

In viewing the 1:120,000 natural color photographs taken when the trees were bare, stereo viewing was sometimes helpful in verifying if a tonally unique area actually had been clearcut by allowing one to determine the height of the vegetation present. This was not critical in summer images where clearcuts were more clearly identifiable by their sharp boundaries and tones alone.

Table 5: Comparison of Small Scale Remotely Sensed Data for the Identification of Clearcutting and Revegetation Assessment in Pennsylvania Hardwood Forests*

FILM/SENSOR	ORIGINAL SCALE	SEASON	ANALYSIS TECHNIQUE	ABILITY TO IDENTIFY CLEARCUTS			ABILITY TO ASSESS REVEGETATION
				IDENTIFY	CLEARCUTS	ASSESS	
Aircraft CIR	1:130,000	Summer	Enlargement Viewing	1		V**	
Aircraft CIR	1:438,000	Summer	Enlargement Viewing	2		G	
Aircraft CIR	1:420,000	Spring	Enlargement Viewing	5		P	
Aircraft NC	1:120,000	Spring	Enlargement Viewing	4**		P	
Aircraft B&W	1:438,000	Summer	Enlargement Viewing	2		F	
Aircraft B&W	1:420,000	Spring	Enlargement Viewing	5		P	
Aircraft BIR	1:438,000	Summer	Enlargement Viewing	2		F	
Aircraft BIR	1:420,000	Spring	Enlargement Viewing	5		P	
Skylab ETC B&W	1:950,000	Summer	Enlargement Viewing	1		F	
Skylab ETC CIR	1:950,000	Summer	Enlargement Viewing	2		G	
Skylab MSC CIR	1:2,850,000	Summer	Enlargement Viewing	4		F	
Skylab MSC NC	1:2,850,000	Summer	Enlargement Viewing	4		P	
Skylab MSC B&W	1:2,850,000	Summer	Enlargement Viewing	5		P	
Skylab MSC BIR	1:2,850,000	Summer	Enlargement Viewing	5		P	
Landsat MSS Band 5	1:3,369,000	Spring/Fall	Enlargement Viewing	5		P	
Landsat MSS Band 5	1:3,369,000	Summer	Enlargement Viewing	4		F	
Landsat MSS Band 5	1:3,369,000	Winter	Enlargement Viewing	3		P	
Landsat RBV	1:1,684,000	Summer	Enlargement Viewing	3		F	
Landsat RBV	1:1,684,000	Winter	Enlargement Viewing	3		P	
Landsat MSS	1:3,369,000	NA	CAV Multi-Band	4		F	
Landsat MSS	1:3,369,000	Summer	CAV Multi-Date	4		P	
Landsat MSS	1:3,369,000	Summer	Unsupervised Digital	4		P	
Landsat MSS	1:3,369,000	NA	Supervised Digital	3		P	

* Legend on following page.

Table 5 Continued:

LEGEND

- CIR - Color Infrared
- NC - Natural Color
- B&W - Black-and-White
- BIR - Black-and-White Infrared
- ETC - Earth Terrain Camera
- MSC - Multispectral Camera
- MSS - Multispectral Scanner
- RBV - Return Beam Vidicon
- NA - Not Applicable
- CAV - Color-Additive Viewing
- ** - Stereoscopic Viewing Helpful
- 1 - 100% of Clearcuts Identifiable
- 2 - 85 to 99% of Clearcuts Identifiable
- 3 - 60 to 84% of Clearcuts Identifiable
- 4 - 25 to 59% of Clearcuts Identifiable
- 5 - 0 to 24% of Clearcuts Identifiable
- V - Very Good, Presence or absence of revegetation clearly identifiable, relative amounts determinable, and approximate height or condition of revegetation available with stereoscopic viewing
- G - Good, Presence or absence of revegetation clearly identifiable, relative amounts determinable
- F - Fair, Some general information on revegetation interpretable from slight tonal differences on original imagery, or through image enhancement
- P - Poor, Little or no information concerning revegetation available

Stereo viewing of the 1:400,000 scale photographs provided topographic relief information, but was of only limited use in clearcut identification and revegetation assessment. The full tree crowns visible in the summer were distinguishable as taller than the enclosed clearcuts; however, when no leaves were present, the ability to differentiate heights at this scale was largely absent. No information about the status of revegetation was possible over that provided by monoscopic viewing of image enlargements. The topographic information available from stereo viewing at this scale may be useful in determining the potential environmental impact resulting from an identified clearcut, and also in locating the site of the cut on maps developed for continuous monitoring purposes.

At the smaller photo scales provided by the Skylab multispectral camera, stereo viewing adds no information. No stereo coverage acquired by the ETC was available.

4.4.3 Comparison of Enlargement Techniques

The ability to clearly enlarge images covering large areas, and to map the information available at the enlarged scale, was crucial to the analyses of this study. The enlargement techniques found most useful for the identification and mapping of clearcuts were overhead and rear-view projection. These techniques allowed the investigator to view a large portion of an image at the mapping scale. There was no need to constantly bring a new portion of the image into view and then realign the overlay being developed. The inability to view the enlarged area stereoscopically was of little significance since stereo viewing was found to be of value

only at the largest scales being considered, and then mostly in the assessment of revegetation. Overhead projection was selected as the enlargement technique for this investigation. Table 6 lists the five enlargement techniques investigated and the relative advantages and disadvantages of each.

4.5 Results of Field Investigation

The most significant finding during the field investigation was the variability in the amount and type of revegetation present on clearcuts of similar ages. In most of the cuts in study area A, a 15 to 20 foot high, young forest stand was well established after an 8 to 10 year period, which is in accordance with Lang's (1975) prediction of 3 to 10 years for a clearcut in Pennsylvania to resemble a young forest when properly carried out, and 15 years if the clearcutting was improperly prescribed or performed. In contrast, study area B contained numerous sites that were composed largely of grasses and ferns with few or no young trees (e.g., the numerous small cuts found near Henry Mills, Appendix B, Figure B 3, were in this condition). This finding helped to explain why these small clearcuts could be noticed after over 10 years; their appearance, especially in the winter when the grasses and ferns would be buried under snow, would be very similar to that of clearcuts only a few years old.

As a result of the finding that many clearcuts in study area B were not returning to forest, a brief comparison of study areas A and B was made on the August 1976 and the December 1978 images. It was found that, in both summer and winter, cuts of similar ages and sizes were less distinct from the surrounding forest in study area A. The smaller cuts,

Table 6: Comparison of enlargement techniques for clearcut identification in hardwood forests using small scale remotely sensed data.

TECHNIQUE USED	ADVANTAGES	DISADVANTAGES
OVERHEAD PROJECTION	<ul style="list-style-type: none"> * 1- Simple equipment is sufficient * 2- Enlarges large areas at one time * 3- Direct mapping capability at chosen scale 4- Variable enlargement possible 5- Enlargement restricted mostly by image quality 	<ul style="list-style-type: none"> * 1- Referencing problems in hilly regions or at large scales 2- No stereo capability 3- Requires transparencies
REAR-VIEW PROJECTION	<ul style="list-style-type: none"> * 1- Direct mapping capability at chosen scale * 2- Enlarges large areas at one time 3- Variable enlargement possible 4- Enlargement restricted mostly by image quality 	<ul style="list-style-type: none"> * 1- Referencing problems in hilly regions or at large scales 2- No stereo capability 3- Requires rear-view projection screen 4- Requires reformatting of imagery into a slide or purchase of a lantern projector
MICROFICHE READER	<ul style="list-style-type: none"> 1- Compact, fairly inexpensive unit 	<ul style="list-style-type: none"> * 1- Small area coverage requires much boundary matching * 2- Enlargement not continuous, dictated by lens used 3- No stereo capability 4- Requires transparencies 5- Referencing problems in hilly regions or at large scales
ZOOM TRANSFER SCOPE	<ul style="list-style-type: none"> * 1- Direct mapping capability 2- Uses transparencies or paper prints 3- Stereo capability if use stereo Zoom Transfer Scope 	<ul style="list-style-type: none"> * 1- Small area coverage requires much boundary matching 2- Relatively expensive equipment needed 3- Enlargement range limited by equipment 4- Poor illumination (could be corrected)
ZOOM STEREO SCOPE	<ul style="list-style-type: none"> 1- Stereo viewing capability 2- Uses transparencies or paper prints 3- Variable enlargement possible 	<ul style="list-style-type: none"> * 1- No direct mapping capability 2- Relatively expensive equipment required 3- Enlargement range restricted by equipment

* - primary considerations

grown back to ferns and grasses, could not be conclusively identified on the summer images, but were more easily seen on the winter images.

The agricultural lands in the study area contained no row crops, but were rather grassy pastures. It was also learned that regeneration on a clearcut site did not necessarily increase with time, but could decrease significantly as a result of grazing by deer. The revegetation of a site, however, should generally be expected to increase or remain constant with time. Recent clearcuts contain a large amount of exposed soil and logging slash throughout the clearcut area.

5. DISCUSSION

5.1 Factors Affecting Clearcut Identifiability

The major factors affecting the usefulness of various remotely sensed data for clearcut identification in hardwood forests were:

(1) season of imagery acquisition, (2) imagery scale and resolution, (3) imagery quality, (4) sensor spectral sensitivity, (5) similarity of surrounding land uses, (6) user familiarity with area of interest, (7) revegetation status, and (8) effects of topography and sun angle on illumination.

5.1.1 Season of Imagery Acquisition

The season of imagery acquisition was found to be very important for clearcut identification in hardwood forests. Comparison of non-growing and growing season photography indicated that, at small scales, virtually no clearcuts can be identified on photos taken at a time when trees are bare. Growing season photography, on the other hand, is very valuable both for identifying clearcuts and the assessment of the status of revegetation within the cuts. No photography of the study area was available during a period with snow cover.

The value of Landsat imagery is also greatly affected by season. Coverage acquired during nonleaf periods when no snow was present was of no value for clearcut identification. Many cuts can be detected on

Landsat MSS and RBV summer images. Surprisingly perhaps, more cuts appear on images acquired when there is a snow cover than during the growing season. Summer images can provide some very limited information in re-vegetation, while no such information can be obtained from winter images alone.

5.1.2 Imagery Scale and Resolution

In order to consistently identify clearcuts of two to five hectares in size, it is best to examine imagery at a scale of approximately 1:200,000 or larger. At this scale, a square four hectare clearcut would be imaged as one sq. mm. Imagery must be acquired at a suitable scale or must have sufficient resolution quality to allow for enlargement without image degradation.

Aerial photographs at a scale of approximately 1:130,000 showed all of the clearcuts in the study area, and yielded substantial information on the extent of revegetation within and among cuts. Nearly 100 percent of the clearcuts were identifiable, and revegetation information was discernible, on 1:438,000 scale photos taken during a suitable season and with a suitable film. CIR film at this scale yields somewhat less information on revegetation, but provides larger area coverage per frame and virtually 100 percent clearcut identification (97% identified in present study). Skylab ETC 1:950,000 scale photos also allowed for 100 percent clearcut identification, as well as information of revegetation. At smaller scales, it became difficult to identify all of the cuts within an area; however, more than 50 percent of clearcuts could be identified even at scales of 1:3,369,000.

Identification, and especially mapping, of clearcuts and revegetation at the original scales of the images was often difficult. As long as the resolution characteristics of the images were such that they could be enlarged without significant information loss, enlargement of the images greatly simplified these tasks. All of the imagery used in this study was enlarged to a scale of approximately 1:125,000 without apparent significant loss of detail.

5.1.3 Imagery Quality

Imagery quality refers to the clarity and sharpness of an image or photo and to its color or tonal contrasts. Quality is governed by the conditions present from the time of imagery acquisition through final product processing. It is important not to confuse the quality of imagery with its usefulness for a particular purpose. Although certain imagery may be of excellent quality, it may provide little to no information for a given investigation, since it may not be recording information in a suitable spectral range or at an appropriate scale.

The quality of the original imagery used in this study was considered satisfactory for assessing its value for clearcut monitoring; however, certain Landsat scenes, particularly the scene from August 1972, was somewhat degraded due to striping.

Although listed separately from quality on computer listings of imagery availability, cloud cover (and haze) could be considered as components of quality since they effect the clarity with which one can detect areas of interest. The presence of clouds or haze may have affected the accuracy of clearcut identification on a number of Landsat images and on the Skylab MSC photos.

Of importance also is the quality of photographic enlargements made for this study from the purchased 70 mm images. Experimentation was done with various exposures and contrast filters to obtain the most satisfactory product for further enlargement by overhead projection or color-additive viewing. Since high magnification is often required for clearcut identification and/or delineation, imagery sharpness is crucial for analysis.

All of the illustrations reproduced in this paper are at least 2 or 3 generations removed from the imagery actually used in the analysis, and so may not depict features of interest as clearly.

5.1.4 Spectral Sensitivity and Resolution of Sensor

The spectral resolution of a film or sensor refers to that portion of the electromagnetic spectrum which is sensed and recorded by it, while its spectral sensitivity determines how many levels of radiation reflectances can be distinguished. Of the films examined, CIR was found to be the most useful for clearcut identification and revegetation assessment. While B&W and BIR photography at a suitable scale and season generally yielded detection of nearly as many clearcuts as the CIR, they provided less information about revegetation, because in the spectral region sensed using the B&W emulsions, the difference in reflectivity of well revegetated and poorly revegetated areas is not as marked as in the region sensed with CIR film.

As shown in Table 1, the suitability of a spectral region for detection of an object of interest is related to scale. Black-and-white photos at a scale of 1:438,000 were very useful for clearcut identification, while 1:2,850,000 scale MSC B&W photos were of little value.

Landsat imagery from bands 5 and 7 was used for analysis. It was found that neither band was of use for clearcut monitoring if acquired when no leaf or snow cover was present, because the reflectance from the exposed ground in a clearcut is not distinguishable from that below leafless trees. During the growing period, band 5 was found to be superior to band 7 because the band 7 image was oversaturated with infrared reflectance from the vast amount of vegetation in the image. Both bands appeared equally useful during periods of snow cover as a result of snow's very high reflectivity at all of the wavelengths being considered. The spectral resolution and sensitivity of the RBV is such that clearcuts can be identified in images acquired with this sensor during both the growing and snow cover periods.

5.1.5 Similarity of Surrounding Land Uses

The study areas for many previously published reports were almost entirely forested, thereby removing the possibility of confusing clearcut areas with other land uses. In the present study, small towns and agricultural lands primarily devoted to pasture were interspersed with the forest. The presence of these other land uses created few identification problems at the larger scales examined. At the smaller scales, clearcuts appeared similar to these other land uses. The effect was particularly significant in the digital analysis of Landsat MSS data since the computer classified pixels strictly on reflectance values without considering such things as the size or configuration of areas being classified. Clearcuts, farmlands, and small urban areas were generally classified as a combination of all of these categories, as well as "other."

The similarity of poorly regenerated clearcuts and grassy pastures led to confusion. The urban areas have large amounts of grass and many trees among the structures.

5.1.6 Familiarity with Area of Interest

A factor that greatly affects the identifiability of clearcuts, and is closely related to the problem of similar surrounding land uses (5.1.5), is the familiarity that the investigator has with an area of interest. An investigator who is familiar with a region can, through prior knowledge of the location of similar appearing land uses, eliminate these areas from his inventory of clearcuts. Recent aerial photography at a scale of 1:130,000 or larger can serve as a reliable substitute for ground experience. Prior familiarity with the area may significantly reduce the amount of field checking that is required to verify clearcut identification, and is especially useful in the analysis of Landsat imagery because of the greater possibility of confusion at Landsat's small scale and relatively poor resolution.

5.1.7 Revegetation Status

The status of revegetation present on a clearcut can affect its identifiability on small scale remotely sensed imagery. A recently cut area contains a significant amount of disturbed soil and slash and is generally clearly distinct from the surrounding forest. Clearcuts that are poorly regenerated, and are composed largely of grass and ferns, are detectable for long periods, but may be confused with other land uses such as pasture. Well regenerated areas remain visible until they more closely resemble forest than cutover land. Clearcuts in the study area remained visible at least 7 to 10 years after cutting.

5.1.8 Topographic and Sun Angle Considerations

The differential illumination that occurs in hilly or rugged areas as a result of the topography can cause confusion in clearcut identification. Although it is possible that a shadow could mask the presence of a cut, areas of shadow are not likely to be confused with clearcuts since cut areas are almost always lighter than their surroundings. The possibility of confusing brightly illuminated areas with clearcuts is more likely. This is especially true during winter when lower sun angle combined with the presence of snow may create increased reflectance from ridges or other topographic features.

5.2 Factors Affecting Data Selection

It is necessary to consider one's information requirements, as well as the resources at one's disposal, before selecting a monitoring methodology. Information requirements that govern the selection of remotely sensed imagery for clearcut monitoring include: (1) thoroughness and accuracy of identification, (2) accuracy of location plotting, (3) detail of age and revegetation, and (4) repetition interval. The funds available for purchasing and analyzing imagery, and the availability of equipment and trained personnel, will also be important in selecting an appropriate data source.

5.2.1 Information Requirements

5.2.1.1 Thoroughness and Accuracy of Identification

The thoroughness and accuracy of clearcut identification will depend upon at least three factors: (1) the scale, resolution, and overall suitability of the imagery being used, (2) the method of imagery analysis, and (3) the investigator's prior knowledge of the area being inventoried.

The thoroughness of clearcut identification that is required by a user is a major consideration in determining what type of remotely sensed data is best suited for his needs. A decision that nearly 100 percent of the existing cuts must be identified dictates the use of photography with sufficient resolution to allow for the identification of 1 or 2 hectare cuts that may be revegetated and similar in appearance to their surroundings. If the identification of approximately 75 percent of the cuts present is deemed satisfactory, Landsat RBV or MSS winter imagery should provide the needed information.

The degree to which an investigator must be certain that he has not confused areas identified as clearcut with other areas will also affect his selection of a data source. Use of CIR aerial photographs at a scale of approximately 1:130,000 will virtually insure correct identification, while the most confusion will result from the analysis of B&W Landsat images. If field checking can be easily performed, the thoroughness and accuracy of clearcut identification need not be as great as if time, access, or other restrictions are limiting.

5.2.1.2 Accuracy of Location Plotting

The accuracy with which the location of a clearcut can be mapped depends upon several factors, including: (1) the accuracy of the base map being used, (2) the quality of the data being examined, (3) how well the investigator can identify clearcut areas, and (4) how well information transfer can be performed. Information transferred from imagery to the base map can be no more accurately located than the inherent accuracy of the base map. The quality of the data and the analyst's ability to

identify clearcuts and their boundaries will determine the accuracy of the information to be plotted. This, combined with the accuracy of the alignment of the map and the imagery, will determine how precisely a clearcut can be plotted. Registration of imagery with the base map will become more difficult as image resolution degrades and as distortion of the imagery increases due to elevation changes.

As mentioned by Murtha and Watson (1975), there is both inter- and intra-image distortion present in imagery acquired by Landsat. This will create some problems in accurately mapping clearcut locations, especially on a year-to-year or other periodic basis. The inaccuracies should be minor enough that, although cuts may not be exactly aligned between one band or year and the next, it should be possible to determine which mapped cuts depict the same cut on the ground and approximately where the cut is located.

5.2.1.3 Detail of Age and Revegetation

The amount of detail required regarding the age and revegetation of clearcut areas affect the selection of remotely sensed data. The best source of information on age and revegetation status can be obtained through analysis of CIR photos that are acquired during full foliage periods. Using this film and season, good results can be had at scales as small as 1:950,000. Very recent cuts appear gray-blue, somewhat older cuts have a smooth pink tone, and older cuts become progressively more red.

Landsat imagery provides significantly less information on clearcut age and revegetation status. No information of this type is obtainable from imagery acquired at times of snow cover. Summer imagery

may yield some information on age by the tones of the cuts. Using a color additive viewer to combine same date, summer images can provide additional information on cut age and revegetation. By comparing imagery acquired during the growing season with snow cover imagery, it is possible to gain some information on revegetation status. If a cut is clearly visible in the summer it is likely that it was recently performed or is poorly revegetated. Cuts that appear very clearly on winter imagery, but poorly or not at all on summer imagery, are likely to have a low vegetation cover of very young trees, grass, or ferns. Cuts that appear less distinctly on the winter imagery and very poorly or not at all on the summer imagery may be occupied by a young forest stand. These comparisons may be affected by other factors such as topographic illumination, haze, or amount of snow cover, and therefore are relatively crude methods of gaining information on the status of revegetation.

5.2.1.4 Repetition Interval

The frequency of clearcut inventory required will dictate in part what types of remotely sensed data will be suitable for monitoring. If data must be acquired every few years, it is unlikely that aerial photography will provide sufficiently frequent data because of the expense of contracting for new photography and the often lengthy time span between coverage of an area by other agencies. Landsat images are available as frequently as every eighteen days (or every nine days if two satellites are operational), if the satellite is functioning properly, and if there is no cloud cover over the area of interest at the time of satellite overpass. Satellite photography may become available on a relatively frequent basis with the advent of the Space Shuttle.

5.2.2 Resource Availability

5.2.2.1 Funds

The availability of funds affects both the type and amount of imagery that may be purchased and the analysis technique that may be employed. Contracting for the acquisition of new photography is far more expensive than purchasing suitable existing imagery. The cost of purchasing existing color photography may be three times that of B&W photography. The cost of analyzing photographs is relatively low.

Landsat imagery is available on a continuous basis and provides very large area coverage per image. Landsat imagery is very inexpensive per square kilometer. Four RBV images are required to cover the area of one MSS scene. Visual analysis of Landsat imagery is no more expensive than that of aerial or space photography. Digital or color-additive analysis of Landsat data increases the cost of investigation if the specialized equipment required must be purchased; however, the use of diazo foils should yield results similar to those gotten from the color-additive viewing without requiring costly equipment. Appendix C contains a table of costs of the imagery used for this study.

5.2.2.2 Equipment and Personnel

The only equipment needed to do a thorough job of clearcut monitoring using any of the small scale imagery discussed in this paper is a machine that will enlarge the image transparencies onto a surface from which they can be mapped. An overhead projector was found to be best suited for this purpose. In order to gain the additional information

available through stereoscopic analysis, a zoom stereoscope must be used, while color-additive viewing requires the use of a color-additive viewer. Digital analysis of Landsat data requires personnel trained in computer programming and access to a suitable computing facility.

5.3 Potential Methodologies for Clearcut Monitoring

Using Small Scale Remotely Sensed Data

The monitoring needs of forest managers will vary as to the type and accuracy of information that is desired regarding the occurrence of clearcutting on lands under their jurisdiction. It is for this reason that not one but three potential methodologies for clearcut monitoring are described. The first, a methodology to allow for very accurate clearcut identification and the maximum amount of revegetation assessment, has the disadvantage of relying exclusively upon aerial (or if available, space) photography, which, due to its relatively high cost, cannot be obtained on a frequent basis. A second more general methodology, employing the use of Landsat satellite data, sacrifices accuracy and detail for timely repetitive coverage. The final methodology combines the use of detailed and general monitoring methodologies to form a continuous monitoring system in which detailed information is acquired when possible, and general trends are determined from Landsat data available in the interims.

5.3.1 Methodology I: Detailed Clearcut & Revegetation Survey

5.3.1.1 Acquisition of Aerial Photography

In order to minimize monitoring expenses, a check should always be made to see if any suitable photography has been taken of the area of interest by a government agency or private firm. The preferred film type,

season, and scale of the photography is color infrared flown in the summer at scales ranging from 1:120,000 to 1:450,000; however, color, black & white, and black and white infrared should in most cases be a satisfactory substitute. Photographs should be purchased as transparencies, so that enlargement will be easily possible for more detailed analysis and transfer to base map scales using overhead projection or other techniques.

Existing small scale photography of many areas is available through the U.S. Geological Survey's Earth Resources Observation Systems (EROS) Data Center in Sioux Falls, South Dakota. Information regarding the available coverage for an area of interest can be obtained by writing the EROS Data Center, and providing the longitude and latitude of the corner points of the area.

Although this study emphasized the use of small scale remotely sensed data, it would be more economical, and would allow for more detailed monitoring, if recent, suitable, large or medium scale photography were available for analysis. No benefit could be gained by acquiring new small scale photography under such circumstances.

If no suitable photography of the study area can be located, it will be necessary to have new photography flown. The scales of photography flown by commercial firms generally are not smaller than 1:80,000. Any clearcutting monitoring programs planned to begin shortly would be able to use the photography being flown for the National High Altitude Data Bank (see section 5.5). Table 7 shows the characteristics of a mission designed to acquire the most suitable imagery for clearcut monitoring.

Table 7:

Preferred mission characteristics for acquisition of small scale aerial photography for clearcut monitoring.

CAMERA: single frame and lens; 93cm (9") format.

FILM/FILTER: color infrared (Kodak Aerochrome IR 2443 or 3443);
yellow filter (Kodak Wratten 12).

SCALE: as close as possible to, but not smaller than 1:130,000 for
stereoscopic coverage to aid in revegetation assessment;
1:450,000 for larger area clearcut monitoring with less
detailed revegetation assessment.

OVERLAP: consecutive, vertical photography with 60% endlap and
20% sidelap.

RESTRICTIONS: cloud and haze-free condition;
growing season (full vegetative cover);
late morning or early afternoon coverage to maximize sun
angle

5.3.1.2 Selection of Base Map

Base maps should be selected to allow for the recording of clear-cut locations at a scale suitable for the user, and compatible with the enlargement capabilities of the original imagery. It is an added benefit if a base map can be found that contains other information such as topography, ownership, tree species, etc., that is useful to a forest manager. The scale of the base maps may be several times larger than the scale of the photographs since, given good quality transparencies, the photo can be enlarged at least ten times. For example, a good quality 1:120,000 scale photo could be enlarged to the scale of 1:15,840, a scale much used in forestry.

5.3.1.3 Location of Clearcuts and Revegetation Assessment

The acquired photography, in the form of film transparencies, should be examined for the presence of clearcuts. At scales of approximately 1:120,000, direct viewing of the photos should be sufficient to detect clearcuts of almost any size. If smaller scale photos were obtained, it would be best to enlarge them to a scale of approximately 1:120,000 using an overhead projector, or other enlargement technique, to help facilitate clearcut identification. It is best to transfer the location of identified clearcuts to an overlay of the selected base map which contains just enough control to allow for easy realignment. This is recommended to eliminate the difficulty of clearly seeing a photo being projected onto a possibly multi-colored and/or detailed map. After completing the overlay, each clearcut should be labeled in some way, and the date of the photography on which it was detected should be noted.

Age and revegetation assessment is done best through stereoscopic analysis of the photos on a zoom stereoscope. Each clearcut that was identified and mapped should be examined at maximum magnification to assess its condition. Individual users should develop some type of categorization system either for the assumed ages of the clearcuts or for their state of revegetation. The result of the assessment of each clearcut should be recorded.

The usefulness of recording the date of clearcut detection and the results of age and revegetation assessment lies in the fact that this information can be compared with the results of prior or subsequent inventories. These comparisons may provide useful information. For example, if cut A was detected on a 1970 photo, and seen to contain low standing revegetation, and was found to contain only grasses on a 1980 photo, it might indicate that the area had been grazed back by deer and should be considered for protective fencing.

5.3.1.4 Field Checking

Little field checking should be required if aerial photography is used as the data source for clearcut monitoring. There should be very little confusion of land uses. The chief reason why field checks might be desired is to investigate areas interpreted as having a poor vegetative cover, in order that detailed information might be obtained so that remedial measures could be undertaken.

5.3.1.5 Limitations of Detailed Survey

The only major limitation of the detailed survey methodology is that it requires aerial photography, which is expensive to obtain unless the costs of acquisition and initial development are covered by another

party. Photography flown for other users may be available for an area of interest, but the frequency of the availability of new photography is often on the order of five to ten years or more. Long periods of time, during which much can occur, may therefore elapse with no monitoring taking place. If information is not required more frequently than five to ten years, detailed surveys should be used.

The cost of acquiring new photography may be reduced if several potential users combine their resources and have a mission flown that will provide information satisfactory to all parties. Rarely would the same conditions be ideal for several users, and compromises in the usefulness of the photography for clearcut monitoring may need to be made.

Space photography was found to provide fairly detailed information for clearcut monitoring. With the advent of the Space Shuttle and the Large Format Camera, it may be possible to acquire photography from this sensor on a more frequent basis, if costs are not too high.

5.3.2 Methodology II: General Reconnaissance Survey

5.3.2.1 Acquisition of Landsat Imagery

Lists of all Landsat imagery available for a particular area of interest can be obtained from the EROS Data Center. A band 5 B&W transparency should be obtained for any good quality, nearly cloud free image taken during the growing season or when a snow cover is present. If weather conditions in the study area are such that numerous suitable images are available each year, the best two or three from each season should be purchased. The purchase of a suitable image taken several years prior to the onset of continuous monitoring would be of value for establishing a base against which to look for changes in the forest which may indicate the occurrence of clearcutting.

If color-additive viewing will be used as an analysis technique, the band 7 transparencies should be purchased for the same dates as the band 5 imagery. It may also be useful to purchase a spring image, which may be helpful in distinguishing clearcuts from other land uses in the area.

5.3.2.2 Selection of Base Maps

Because of the very small scale of the Landsat imagery, it is necessary that the base map selected for the recording of clearcut locations not be of so large a scale that degradation of imagery occurs during enlargement of the imagery to map scale. This is especially important since few reference points are identifiable on the Landsat imagery for use as guides for plotting the clearcut locations. In this study, satisfactory results were achieved by transferring information to a map at a scale of approximately 1:125,000; however, it is not recommended that maps of significantly larger scale be used.

5.3.2.3 Familiarization with Study Area

In contrast to aerial photography, on which almost all major land uses can be distinguished from one another, several land uses may give spectral signatures that appear almost identical and indistinguishable on Landsat imagery. Only personnel who are or will become familiar with the locations of relatively permanent land uses such as farming and small urban development, which may be confused with clearcut areas during image analysis, should perform the Landsat image analysis. This will allow for a more accurate inventory of clearcutting.

5.3.2.4 Location of Clearcuts and Possible Revegetation Assessment

The B&W band 5 transparencies should be enlarged and analyzed by persons familiar with the study area in order to identify those areas believed to be clearcuts. A single base map overlay, identifying the clearcuts detected on the various images examined, should be maintained for the study area at base map scale.

It may be possible over time to obtain some information on revegetation status of the identified clearcuts. When a clearcut becomes difficult to detect, it is likely that it is well revegetated. Cuts clearly visible in winter, but not visible in summer, are likely to contain vegetation that is short enough to be covered by snow. Revegetation assessment must be considered to yield only crude estimates.

If equipment for color-additive viewing is available, it is possible to improve the identifiability of clearcuts from other land uses by simultaneously viewing imagery taken at a different time of the year, and the assessment of age and revegetation by simultaneously viewing imagery taken in bands 5 and 7 on the same date. The acquisition and color-additive viewing of annually obtained MSS imagery will allow for the exact identification of the year in which any particular clearcut was performed.

5.3.2.5 Field Checking

Field checking may be desired to ascertain the identity of areas identified as clearcuts, but with a poor degree of certainty. Areas suspected of being poorly revegetated may also be field checked to determine their condition and whether or not remedial measures should be taken.

5.3.2.6 Limitation of Reconnaissance Survey

There are several limitations to the reconnaissance survey methodology, chief among them being the inability to detect nearly 100 percent of existing clearcuts. The relatively low resolution of the MSS and RBV sensors makes it difficult to detect small cuts. A prior knowledge of the area is needed to distinguish clearcuts from other land uses that have similar tonal appearances on Landsat imagery. Also important is the fact that little information regarding revegetation can be obtained from a Landsat image. Revegetation information must be inferred from a comparison of two bands or dates of imagery. Although a Landsat satellite passes over a given ground location every 18 days, there is no guarantee that conditions will be favorable for the acquisition of an image of suitable quality for clearcut monitoring. A greater amount of field checking is also required for this survey method.

5.3.3 Methodology III: Combined Monitoring System

If one combines the key components of the detailed and general monitoring methodologies, one can create a system in which the major limitations of each individual system are substantially minimized. The detail provided by the analysis of aerial photographs allows for the detection of clearcuts that may not be visible on Landsat imagery, and for the more thorough assessment of age and revegetation status. If photographs can be obtained at the beginning of a monitoring program, their analysis will familiarize the investigator with the study area, and thereby improve the subsequent analysis of the Landsat imagery. The very low cost and repetitive nature of Landsat imagery makes it a useful

data source for the monitoring of clearcutting during periods when no new aerial photography is flown. Those clearcuts not detected on the Landsat imagery can be identified at a later time when aerial photos become available. In the interim, significantly more information will be available at little expense, through the Landsat analysis.

The remotely sensed data should be of the same form, and obtained from the same sources or in the same manner as described in Sections 5.3.1.1 and 5.3.2.1. Ideally, a detailed survey using aerial photography should be considered the first step in a continuous monitoring program, since it establishes a thorough inventory of clearcuts present at the start of the program and familiarizes the analyst with the study area, thereby improving his or her ability to analyze future Landsat imagery. Once the location of existing clearcuts and areas that appear similar to clearcuts on Landsat images have been identified and mapped, future clearcuts can be detected as changes in land use from previous imagery. If images are acquired each year, all of the clearcuts that occurred in the interim between image acquisition will still be in a relatively disturbed state with little revegetation present. This will allow for easier identification of clearcuts than is the case when Landsat is used to inventory an area where clearcuts of various ages and levels of revegetation need to be identified.

Aerial photographs should be purchased whenever they become available through other agencies, or contracted for when information needs require it and funding is available. Good quality Landsat imagery (MSS and RBV) taken during the growing season or when a snow cover is present, should be purchased when it becomes available.

Analysis of the various types of imagery should be carried out in the same way as was described in Sections 5.3.1.3 and 5.3.2.4. Due to the different scales of the aerial photography and the Landsat imagery, it may be necessary to use base maps of two different scales. Field checks should be made at the users discretion, but the number should be intermediate between that needed for the detailed and general surveys.

The thoroughness of this methodology will be limited by the amount and frequency of imagery obtained and by the inherent limitations on the information that can be derived from the various types of imagery examined.

5.4 Examination of Potential Transferability of Findings

After completion of the analysis of the remotely sensed data of the study area, a less comprehensive examination of certain remotely sensed data for a forested region in New York State was conducted in order to determine in a general way whether the results obtained regarding the monitoring of clearcutting in the study area were transferable, at least in part, to other regions where the terrain was more rugged, the forests were not predominantly hardwood, and the timber harvesting techniques, including "clearcutting," were different than those in the Allegheny National Forest.

5.4.1 Methods and Materials of Comparison Investigation

Two sites were selected in New York's Adirondack State Park, based upon the availability of documentation on several clearcuts occurring within them. One site is located just east of Catalin Lake in the central portion of the Park, while the other lies just northeast of Loon Lake, in

the north central portion of the Park (Figure 18). Rather than being predominantly hardwood forests, the Adirondack forests are composed of hardwood, coniferous, and mixed forest areas. This area was selected for the comparison study because it was known that Park officials were anxious to determine if small scale remotely sensed imagery could be employed to monitor clearcutting within the Park.

Ground data for the site near Catalin Lake was in the form of a vegetative description map of the Archer and Anna Huntington Wildlife Forest Station on which were marked the locations of harvest sites and their year of harvest. Similar maps of portions of the land holdings of Sher-Don Associates, Inc. had been marked to show the locations and year of harvest of clearcuts performed by that firm. Shown in Table 8 is a list of the remotely sensed data of the Adirondack region obtained for examination.

The 1:120,000 CIR photographs of the study sites were stereoscopically examined using the zoom stereoscope in order to see if the known clearcuts could be located and identified. The Landsat imagery was photographically enlarged approximately 5 times to form B&W negative transparencies which were then examined at a scale of approximately 1:125,000 with the aid of an overhead projector. Overhead viewing was also used to examine the Skylab photograph.

5.4.2 Results of Transferability Examination

Harvested areas in the Adirondack study sites could be easily identified through monoscopic or stereoscopic analysis of the CIR aerial photographs. The strip clearcuts on the Sher-Don lands were clearly identifiable by the appearance of alternating rows of gray or pink clearcut

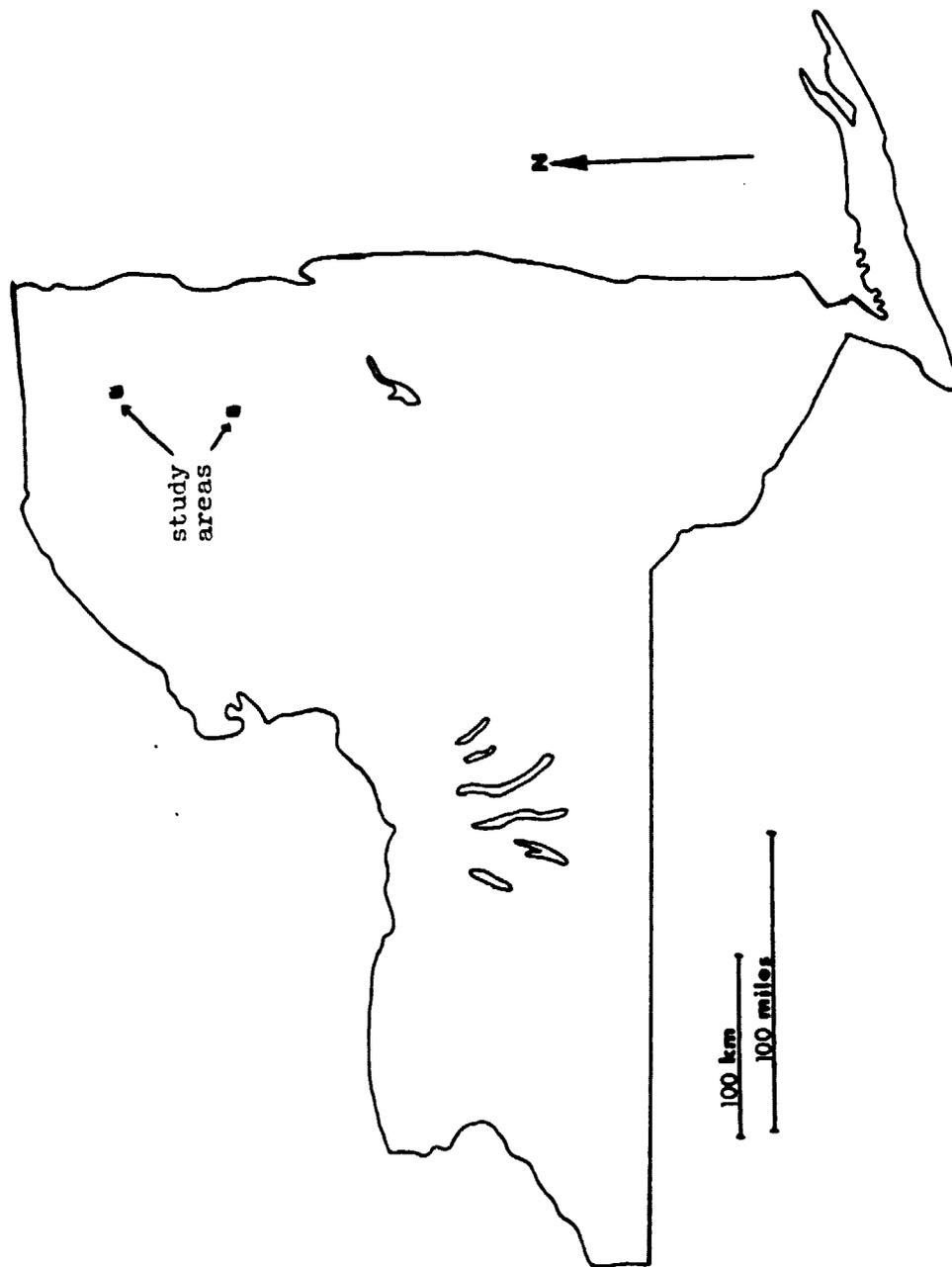


Figure 18: Location of study areas in the Adirondack region of New York State.

PLATFORM*	Image ID #**	FRAME #	DATE	FILM/BAND (wavelength μ m)	SCALE	STEREO
Aircraft	NA	149-150 155-156	6/19/79	CIR (.510 - .900)	1:120,000	Y
Skylab (ETC)	G30B085349000	NA	9/10/73	B&W (0.5 - 0.7)	1:950,000	N
Landsat (MSS)	83035015012X0	NA	2/18/79	5 (0.6 - 0.7)	1:3,369,000	N
(RBV)	83053015000XC	NA	8/17/79	NA (.505 - .750)	1:1,684,000	N

Table 8: Remotely sensed data selected for transferability analysis.

LEGEND: * - see literature review for platform descriptions; ** - From EROS computer listings; ETC - Earth Terrain Camera; MSS - Multispectral Camera; RBV - Return Beam Vidicon Camera; NA - not available; Y - yes; N - no

strips between deeper red or red-brown rows of standing forest. Partially cut stands, probably being harvested by the selection cutting method, were also clearly visible. The cuts in the Huntington Forest could be easily identified by the somewhat mottled appearance of the cut areas. This resulted from small darker red patches of uncut trees or established revegetation, appearing among the smoother textured, pink or pink-gray areas where nearly all of the tree cover had been removed, and revegetation was at an early stage. The appearance of logging roads also helped in the identification of these areas.

Skylab photography covered only the Huntington Forest. Harvested areas could be identified by their lighter appearance in comparison to the surrounding forest. The cuts appeared less distinct than those that were identified on the Skylab photographs of the Allegheny region.

The Landsat MSS image, taken in the winter with snow cover present, was only somewhat useful for clearcut identification. Certain known cuts were detectable by their light tone which could be distinguished from the lighter tone of the small lakes and the darker tone of the surrounding forest; however, differential lighting resulting from the rugged topography caused many areas not believed to be cut to appear so. Nonforested wetlands, with vegetation low enough to be covered by snow, may also be confused with clearcuts. The strip cuts on the Sher-Don lands were not detectable on the MSS winter images.

Certain areas of cutting could be identified on the summer RBV image as lighter toned areas amid the darker forest. Those cuts done in the past few years were most easily detectable. The strip cuts on the Sher-Don lands were not detectable, perhaps due in part to scattered clouds over the area.

5.4.3 Discussion of Potential Transferrability

The results of an examination of several small scale images of portions of the Adirondack Park in New York State indicate that characteristics unique to a region can affect the identifiability of clearcut areas. These characteristics reduce the possibility of detecting harvest activities on some forms of imagery while not affecting it on others. Several factors could be considered as possibly contributing to the increased difficulty of clearcut detection in the Adirondack region, chief among these being greater topographic relief and associated illumination variations, differences in harvesting practices including amount of timber felled and removed, amount of soil disturbance, distribution of slash, the amount of vegetation present after harvest, and the presence of coniferous and mixed forest types.

The greater topographic relief in the Adirondacks created more difficulty in distinguishing areas that were simply darker or lighter than their surroundings, from those that appeared lighter as a result of being clearcut. These problems are far less significant at a scale of 1:120,000 than at a scale of 1:3,369,000.

The clearcutting in the Allegheny region was almost exclusively block cutting in which virtually all of the trees in the block were removed. In the Adirondack region, the known clearcuts included strip cuts and cutover areas resulting from the removal cutting in a shelterwood harvesting system. The shelterwood, after removal cutting, resembles a clearcut after establishment of revegetation, but is not a true clearcut; however, by Adirondack Park Agency regulations, the removal cut constitutes a clearcut. One must first be certain of what one is expected

to monitor before one determines whether other studies would indicate that a monitoring task can or cannot be accomplished. The fact that strip clearcuts were present and that the shelterwood cuts were at no time as devoid of an overstory or revegetation understory as the clearcuts in the Allegheny region helps to explain, at least in part, why their detection was more difficult.

Although not demonstrated by the study, it can be hypothesized that clearcuts occurring in more similar forest types or harvested in a more similar manner to those in the Allegheny region would be more easily discernable in the Adirondacks. The results of this study and the methodologies suggested for clearcut monitoring would be best suited to regions of hardwood forests where nearly all trees are removed in a single cutting and where the topography is not excessively mountainous.

5.5 Future Small Scale Remotely Sensed Data Sources

The near future promises the introduction of new programs and systems for acquiring remotely sensed data. A program is underway to acquire aerial photography of the entire conterminous United States, while in the field of remote sensing from space there are at least two new systems being developed: the Space Shuttle Large Format Camera and the Landsat Thematic Mapper.

A program to create a National High Altitude Photography Data Bank is a four to five year, multi-agency effort to image the entire conterminous United States with high altitude aerial photographs, beginning in the spring of 1980. Black-and-white photos will be acquired at a scale of approximately 1:80,000 and color infrared photos will be at a scale of

approximately 1:58,000. All coverage will be stereoscopic with a 23 cm format (Cornell Remote Sensing Newsletter, 1979). These photographs, especially those taken with color infrared film, should be very well suited for the identification of clearcutting, if they are acquired during the growing season. Information interpreted from these photos will be useful in gaining a familiarity with an area to be monitored, and for establishing a baseline inventory of clearcuts.

The development of a Large Format Camera is being funded by NASA for testing and use on Space Shuttle missions. The first launch of the Shuttle is scheduled for early in the 1980s. The film format of the camera will be 23 x 46 cm, with each frame covering 225 x 450 km, from an orbital altitude of 300 km (Doyle, 1978). The photographic scale of 1:1,000,000 and resolution of 15 m would be almost identical to the very useful photography obtained with the Skylab Earth Terrain Camera.

Originally scheduled to be launched in September 1981 as part of the Landsat D payload, the Thematic Mapper is now scheduled for earliest launch in mid-1983 on Landsat D-Prime (Covault, 1980). The Thematic Mapper will be a seven-channel scanner, covering a ground swath of 185 km with a spatial resolution of approximately 30 m in its six nonthermal bands, and 120 m in the seventh thermal band. The bandwidths are selected to maximize vegetation analysis capabilities. Contrasts between vegetative and nonvegetative features, as well as contrasts within vegetative classes, are emphasized by one spectral region, while another emphasizes contrast between soil and vegetation. The better discrimination of both of these features, as well as the increased resolution, will aid in clearcut monitoring using satellite imagery.

6. CONCLUSIONS

Monitoring of clearcutting in predominantly hardwood forests can be performed with varying degrees of accuracy and detail using small scale aerial photography, Skylab photography, and Landsat imagery. It is known that large scale aerial photography can provide accurate and economical information for clearcut monitoring; however, the successful application of small scale imagery makes investigations of large areas more rapid and cost efficient.

It was possible to identify all of the clearcuts in the Allegheny study area using small scale aerial and Skylab photography. The season of acquisition is more crucial than either film type or scale. The maximum number of clearcuts can be identified, and the maximum information regarding revegetation can be determined on photography acquired during the growing season. With this provision met, the most detailed monitoring can be performed through stereoscopic analysis of magnified color infrared photography at original scales of approximately 1:130,000. Such analysis allows for the detection of clearcuts as small as 0.5 hectares or less, and a general assessment of the amount and condition of the revegetation present.

Aerial photography at scales of approximately 1:450,000 was also found very useful. While CIR stereo photos at the 1:130,000 scale allowed for the greatest amount of information on revegetation, the 1:450,000

scale photos provided larger area coverage and were on par with the 1:130,000 photos in the value for clearcut identification. The scale and resolution properties of all of the imagery analyzed in this study allowed only for revegetation assessment (the re-establishment of vegetation of any sort), rather than the more desirable assessment of regeneration (the re-establishment of desired tree species). Photography at a scale of 1:950,000 taken from Skylab also allowed for the detection of all of the known cuts in the Allegheny study area; however, it was helpful to have a prior knowledge of the area so that similar appearing areas such as pastures could be subtracted from the inventory of clearcut lands.

Landsat Multispectral Scanner and Return Beam Vidicon imagery, due to their smaller scale and lower resolution, were found to be less reliable sources of information for thorough clearcut monitoring. Photo-interpretation of enlarged B&W band 5 images revealed no clearcuts if the images were acquired when no leaf or snow cover was present. Clearcuts could be detected on images acquired during the growing season or when there was snow on the ground. While summer imagery allowed for some very rough assessment of age or revegetation, more clearcuts could be detected on the snow cover imagery. Clearcuts as small as five acres could be detected. The higher resolution of the REV imagery was helpful for more clearly detecting clearcut areas. Color-additive viewing of multi-band or multi-date imagery was useful in helping to establish age or clearcuts, to distinguish them from other land uses, and to yield rough information on revegetation status.

Although many previous investigators working mostly in coniferous forests where few other land uses were present, favored digital analysis of Landsat imagery for clearcut monitoring, this investigation found it to be of little value. The tonal variations within the clearcuts, the small range of spectral values composing the image examined, and the similar appearance of other land uses made digital classification of the clearcuts difficult and inaccurate. Prior knowledge of the location of the more permanent land uses is very important to an analysis of Landsat data by any means since it helps prevent the misclassification of these areas as clearcuts.

The preferred method of enlargement for facilitating interpretation and creating base map overlays of the location of identified clearcuts was overhead projection. This is a simple, inexpensive enlargement technique, which enlarges large areas at one time and allows for direct mapping from the enlarged image. When using overhead projection it is best to plot the information interpreted onto an uncluttered overlay of the base map.

Small scale remotely sensed imagery can be employed in a variety of clearcut monitoring methodologies. The greatest accuracy and detail can be obtained through analysis of aerial photography, but this is costly and often relatively infrequently acquired. Available at a much lower cost and theoretically far more frequently, Landsat data has the disadvantage of providing a less thorough and detailed survey of clearcutting. A combination of these two data sources allows for a continuous monitoring system in which detailed information is obtained from photos when available or necessary, and general trends are determined from Landsat data during the interim.

A brief analysis of several small scale images of a more mountainous, less predominantly hardwood forest region in the Adirondack Mountains yielded less encouraging results for clearcut monitoring. Harvested areas were easily identified on summer color infrared photos at a scale of approximately 1:120,000. Identification on Skylab photography was somewhat more difficult, while Landsat analysis appeared to be significantly less successful than in the Allegheny region. It is believed that the more rugged topography and the use of different harvesting techniques were major factors responsible for the apparent decrease in clearcut detectability.

Future monitoring efforts should be aided by the imagery provided by the Large Format Camera to be carried by the Space Shuttle, and by the Thematic Mapper to be carried on Landsat D-Prime. The Thematic Mapper's expected 30 m resolution, its seven spectral bands, and the repetitive nature of its acquisition, should greatly improve continuous monitoring efforts. The nationwide high altitude photography being acquired could serve as a very good data source for the start of a clearcut monitoring program.

LITERATURE CITED

Aggers, L.W. and E.B. Kelley. 1976. Douglas County Forest Cover Condition Mapping and Forest Volume Inventory. p. 218-229. In Proc. Fall 1976 Convention Amer. Soc. of Photogrammetry. Held Seattle, Washington. A.S.P., Falls Church, Va.

Aldrich, R.C. 1971. Space Photos for Land Use and Forestry. Photogrammetric Eng'g. 37:4:389-401

_____. 1975. Detecting Disturbance in a Forest Environment. Photogrammetric Eng'g and Remote Sensing. 41:1:39-48

Aldrich, R.C., N.X. Norick, and W.J. Greentree. 1975. Forest Inventory: Land-Use Classification and Forest Disturbance Monitoring. p. 6-25. In Evaluation of ERTS-1 Data for Forest and Rangeland Surveys. Research Paper PSW-112. U.S.D.A. Forest Service

Aldrich, R.C., E.H. Roberts, W.J. Greentree, N.X. Norick, and T.H. Waite. 1976. Forest Inventory: Forest Resource Evaluation, Sampling Design, and Automated Land Classification. p. 9-34. In Evaluation of Skylab (EREP) Data for Forest and Rangeland Surveys. Research Paper PSW-113. U.S.D.A. Forest Service

Aviation Week & Space Technology. 1980. Landsat-2 Returned to Active Use. 112:26:58

Borden, F.Y.; D.N. Applegate, B.J. Turner, B.F. Merembeck, E.G. Crenshaw, H.M. Lachowski, and D.N. Thompson. 1977. Satellite and Aircraft Multi-spectral Scanner Digital Data Users Manual. Office for Remote Sensing of Earth Resources. The Pennsylvania State University. University Park, Pa. 294 pp.

Bryant, E., A.G. Dodge, and M.J.E. Eger. 1979. Small Forest Cuttings Mapped with Landsat Digital Data. p. 971-981. In Proc. 13th Int'l Sym'p. on Remote Sensing of Environment. Held Univ. of Mich., Ann Arbor, Mich. Envir. Res. Inst. of Mich., Ann Arbor, Mich.

Burk, D., 1970. The Clearcut Crisis. Jursnick Printing. Great Falls, Mont. 152 pp.

Carnegie, D.M., and B.T. Fine. 1977. Vegetation Patterns. p. 243-262. In Skylab Explores the Earth. NASA Lyndon B. Johnson Space Center. Houston, Tx.

Catto, A.T. 1965. Aerial Photography for Mapping Cut-over Areas. Pulp and Paper Canada. 66:3:120-124

Colwell, R.N. 1968. Determining the Usefulness of Space Photography for Natural Resources Inventory. p. 249-290. In Proc. 5th Int'l. Symp. on Remote Sensing of Environment. Held Univ. of Mich., Ann Arbor, Mich. Envir. Res. Inst. of Mich., Ann Arbor, Mich.

Colwell, R.N., and J.D. Lent. 1969. The Inventory of Earth Resources on Enhanced Multiband Space Photography. p. 133-143. In Proc. 6th Int'l. Symp. on Remote Sensing of Environment. Held Univ. of Mich., Ann Arbor, Mich. Envir. Res. Inst. of Mich., Ann Arbor, Mich.

Condit, H.R. 1970. The Spectral Reflectance of American Soils. Photogrammetric Eng'g. 36:9:955-966

Cort , E.S., J.A. Lynch, and W.E. Sopper. 1978. Timber Harvesting Practices and Water Quality in the Eastern United States. Jour. of Forestry. 76:8:484-488

Cornell Remote Sensing Newsletter. 1979. Nationwide High Altitude Photography. 8:4:1

Covault, C. 1980. Problems Force Landsat D Restructure. Aviation Week & Space Technology. 112:23:20-22

Doyle, F.J. 1978. The Next Decade of Satellite Remote Sensing. Photogrammetric Eng'g. and Remote Sensing. 44:2:155-164

Eastman Kodak Company. 1972. Kodak Aerial Films and Photographic Plates. Eastman Kodak Co. Rochester, NY 28 pp.

Gabriel, H.W. 1972. Aesthetics and Timber Harvesting in the Northern Rockies. p. 78-92. In Forest Land Use and the Environment (R.M. Weddle, ed.). Univ. of Montana Printing Dept. Missoula, Mont.

Gearhart, P.H. 1980. Personal Communication

Gordon, R.B. 1937. The Botanical Survey of Allegany State Park. p. 23-88. In New York State Museum Handbook 17. The Univ. of the State of New York, Albany

Hardy, E.E., J.E. Skaley, C.P. Dawson, G.D. Weiner, E.S. Phillips, and R.A. Fisher. 1975. Enhancement and Evaluation of Skylab Photography for Potential Land Use Inventories. NASA Contract NAS 9-13364. 174 pp.

Hassinger, J.D., S.A. Liscinsky, and S.P. Shaw. 1975. Wildlife. p. 65-81. In Clearcutting in Pennsylvania. School of Forest Resources - College of Agr., The Pennsylvania State Univ., University Park, Pa.

Hawley, D.L. 1979. Forest Inventory of Clearcuts Utilizing Remote Sensing Techniques. p. 1385-1407. In Proc. 13th Int'l. Symp. on Remote Sensing of Environment. Held Univ. of Mich., Ann Arbor, Mich. Envir. Res. Inst. of Mich., Ann Arbor, Mich.

Heath, G.R. 1974. ERTS Data Tested for Forestry Applications. Photogrammetric Eng'g. 40:9:1097-1091

Heller, R.C. 1975. Summary. p. 1-5. In Evaluation of ERTS-1 Data for Forest and Rangeland Surveys. Research Paper PSW-112. U.S.D.A. Forest Service

Johnson, G.R., E.W. Barthmaier, T.W.D. Gregg, and R.E. Aulds. 1979. Forest Stand Classification in Western Washington Using Landsat and Computer-Based Resource Data. p. 1681-1696. In Proc. 13th Int'l. Symp. on Remote Sensing of Environment. Held Univ. of Mich., Ann Arbor, Mich. Envir. Res. Inst. of Mich., Ann Arbor, Mich.

Kalensky, Z. and L.R. Scherk. 1975. Accuracy of Forest Mapping from Landsat Computer-Compatible Tapes. p. 1159-1167. In Proc. 10th Int'l. Symp. of Remote Sensing of Environment. Held Univ. of Mich., Ann Arbor, Mich. Envir. Res. Inst. of Mich., Ann Arbor, Mich.

Kalensky, Z.D., W.C. Moore, G.A. Campell, D.A. Wilson, and A.J. Scott. 1979. Forest Statistics by ARIES Classification of Landsat Multispectral Images in Northern Canada. p. 789- 811. In Proc. 13th Int'l. Symp. on Remote Sensing of Environment. Held Univ. of Mich., Ann Arbor, Mich. Envir. Res. Inst. of Mich., Ann Arbor, Mich.

Kan, E.P. and Dillman. 1975. Timber Type Separability in Southwestern United States on Landsat-1 MSS Data. p. 135-157. In NASA Earth Resources Survey Symp. Vol. IA. NASA TMX-58168. Held NASA/Johnson Space Flight Center, Washington, D.C.

Kirby, C.L. 1973. Forest and Land Inventory Using ERTS Imagery and Aerial Photography in the Boreal Forest Region of Alberta, Canada. p. 127-136. In 3rd Earth Resources Technology Satellite-1 Symp. NASA SP-351. Held NASA Goddard Space Flight Center, Washington, D.C.

Kondratyev, K.Y. 1969. Radiation in the Atmosphere. Academic Press, NY 912 pp.

Knipling, E.B. 1969. Leaf Reflectance and Image Formation on Color Infrared Film. p. 17-29. In Remote Sensing in Ecology (P.L. Johnson, ed.). Univ. of Georgia Press. Athens, Georgia

Lang, L. 1975. Aesthetic Considerations. p. 1-8. In Clearcutting in Pennsylvania. School of Forest Resources - College of Agr. The Pennsylvania State Univ., University Park, Pa.

Leak, W.B., D.S. Solomon, and S.M. Filip. 1969. A Silvicultural Guide for Northern Hardwoods in the Northeast. Research Paper NE-143. U.S.D.A. Forest Service. 34 pp.

Lee, Y.J. 1975. Are Clearcut Areas Estimated from Landsat Imagery Reliable? p. 105-114. In NASA Earth Resources Survey Symp. Vol. IA. NASA TMX-58168. Held NASA/Johnson Space Center, Houston, Tx.

_____. 1976. Computer Assisted Forest Land Classification in British Columbia and the Yukon Territory: A Case Study. p. 240-250. In Proc. Fall 1976 Convention Amer. Soc. of Photogrammetry. Held Seattle, Washington. A.S.P., Falls Church, Va.

Lee, Y.J., F. Towler, H. Bradatsh, and S. Finding. 1977. Computer-Assisted Forest Land Classification by Means of Several Classification Methods on the CCRS Image-100. p. 37-47. In Proc. 4th Canadian Symp. on Remote Sensing. Held Quebec City, P.Q., Canada

Lee, Y.J. 1980. Personal Communication

Lillesand, T.M. and R.W. Kiefer. 1979. Remote Sensing and Image Interpretation. John Wiley & Sons. NY 612 pp.

Lynch, J.A., E.S. Corbett, and R.J. Hutnik. 1975. Water Resources. In Clearcutting in Pennsylvania. School of Forest Resources - College of Agr., The Pennsylvania State Univ., University Park, Pa.

Marquis, D.A. 1975. The Allegheny Hardwood Forest of Pennsylvania. General Technical Report NE-15. U.S.D.A. Forest Service. 32 pp.

_____. 1979. Shelterwood Cutting in Allegheny Hardwoods. Jour. of Forestry. 77:3:140-144

Metzger, F.T. and C.H. Tubbs. 1971. The Influence of Cutting Method on Regeneration of Second-Growth Northern Hardwoods. Jour. of Forestry 69:9:559-564

Meyer, M.D., D.W. French, R. Latham, C. Nelson, and R. Douglass. 1971. Vigor Loss in Conifers Due to Dwarf Mistletoe. Annual Prog. Report for Earth Resources Survey Program, NASA. Univ. of Minn. College of Forestry. 39 pp.

Morris, W.G. 1970. Photo Inventory of Fine Logging Slash. Photogrammetric Eng'g. 36:12:1252-1256

Murtha, P.A. and E.K. Watson. 1975. Mapping of Forest Clear-cutting South Vancouver Island, from Landsat Imagery. p. 257-263. In Proc. 3rd Canadian Symp. on Remote Sensing. Held Edmonton, Canada

NASA. 1974. Skylab Earth Resources Data Catalog. NASA/Lyndon B. Johnson Space Center, Houston, Tx. 359 pp.

_____. 1978. Skylab EREP Investigations Summary. NASA/Lyndon B. Johnson Space Center, Houston, Tx. 386 pp.

Nelson, J.C., B.A. Roach, O.L. Frank, and W. Ward. 1975. Timber management. p. 33-49. In Clearcutting in Pennsylvania. School of Forest Resources - College of Agr., The Pennsylvania State Univ. University Park, Pa.

Northcross, S. 1979. Big Enterprise Emerges Slowly from Pennsylvania Hinterlands. Timber Harvesting. 27:11:12-16

Patric, J.H. 1976. Soil Erosion in the Eastern Forest. Jour. of Forestry. 74:10:671-677

Pennock, R. Jr., G.W. Wood, P.W. Jr. Shogren, K. Reinhart, C. Miles, and P. Younkin. 1975. The Forest Soil. p. 21-32. In Clearcutting in Pennsylvania. School of Forest Resources - College of Agr., The Pennsylvania State Univ. University Park, Pa.

Pennsylvania Dept. of Commerce. 1972. 1972 Pennsylvania Industrial Directory. Harrisburg, Pa. 1067 pp.

Reeves, R.G. ed. 1975. Manual of Remote Sensing. 2 Vols. American Society of Photogrammetry. Falls Church, Va. 2144 pp.

Rudd, R.D. 1971. Macro Land-Use Mapping with Simulated Space Photos. Photogrammetric Eng'g. 37:4:365-372

Sabins, F.F. Jr. 1978. Remote Sensing Principals and Interpretation. W.H. Freeman and Co. San Francisco, Calif. 426 pp.

Salerno, A.E. 1976. Aerospace Photography. p. 11-83. In Remote Sensing for Environmental Sciences. (E. Schanda, ed.). Springer-Verlag, Berlin

Sayn-Wittgenstein, L. and W.C. Moore. 1972. The ERTS Experiments of the Canadian Forest Service. p. 705-712. In Proc. 1st Canadian Symp. on Remote Sensing. Held Ottawa, Canada

Sayn-Wittgenstein, L. 1977. Remote Sensing and Today's Forestry Issues. p. 267-276. In Proc. 11th Int'l. Symp. on Remote Sensing of Environment. Held Univ. of Mich., Ann Arbor, Mich. Envir. Res. Inst. of Mich., Ann Arbor, Mich.

_____. 1978. Recognition of Tree Species on Aerial Photographs. Forest Management Inst. Canadian Forest Service, Ottawa, Canada. 97 pp.

Shepherd, J. 1975. The Forest Killers. Weybright and Talley, NY 423 pp.

Stoddard, C.H. 1978. Essentials of Forestry Practice. 3rd ed. John Wiley & Sons, Inc. NY 387 pp.

- Strahler, A.H., T.L. Logan, and C.E. Woodcock. 1979. Forest Classification and Inventory System Using Landsat, Digital Terrain, and Ground Sample Data. p. 1541-1557. In Proc. 13th Int'l. Symp. on Remote Sensing of Environment. Held Univ. of Mich., Ann Arbor, Mich. Envir. Res. Inst. of Mich., Ann Arbor, Mich.
- Twight, P.A. and L.S. Minckler. 1972. Ecological Forestry for the Northern Hardwood Forest. National Parks and Conservation Assoc. Washington, D.C. 14 pp.
- U.S.D.A. Forest Service. 1973. The Outlook for Timber in the United States. Forest Resource Report No. 20. 367 pp.
- U. S. Geological Survey. 1979. Landsat Data Users Handbook
- Ward, W.W. 1974. Clearcutting in the Hardwood Forests of the Northeast. p. 67-78. In Clearcutting: A View from the Top. (E.C.J. Horwitz ed.). Acropolis Books, Ltd. Washington, D.C.
- Welch, R. 1974. Skylab-2 Photo Evaluation. Photogrammetric Eng'g. 40:10:1221-1224
- _____. 1976. Skylab S-190B ETC Photo Quality. Photogrammetric Eng'g. and Remote Sensing. 42:8:1057-1060
- Wightman, J.M. 1972. High Altitude Photography Records and Monitors Logging Operations. p. 137-143. In Proc. 1st Canadian Symp. on Remote Sensing. Held Ottawa, Canada
- Williams, D.L. 1976. A Canopy-Related Stratification of a Southern Pine Forest Using Landsat Digital Data. p. 231-239. In Proc. Fall 1976 Convention Amer. Soc. of Photogrammetry. Held Seattle, Washington. A.S.P., Falls Church. Va.
- _____. 1979. Canopy Closure in Pine Forests in North Carolina. p. 19-28. In Monitoring Forest Canopy Alterations Around the World with Digital Analysis of Landsat Imagery. NASA. 45 pp.
- Wolf, P.R. 1974. Elements of Photogrammetry. McGraw Hill, Inc. NY 562 pp.
- Wood, N. 1971. Clearcut: The Deforestation of America. Sierra Club, San Francisco, Calif. 151 pp.
- Yurich, S. 1973. Testimony presented in Hearings before the Subcommittee on Public Lands of the Committee on Interior and Insular Affairs, House of Representatives. 93rd Congress. p. 2-12. U.S. Govt. Printing Office, Washington, D.C.

APPENDICES

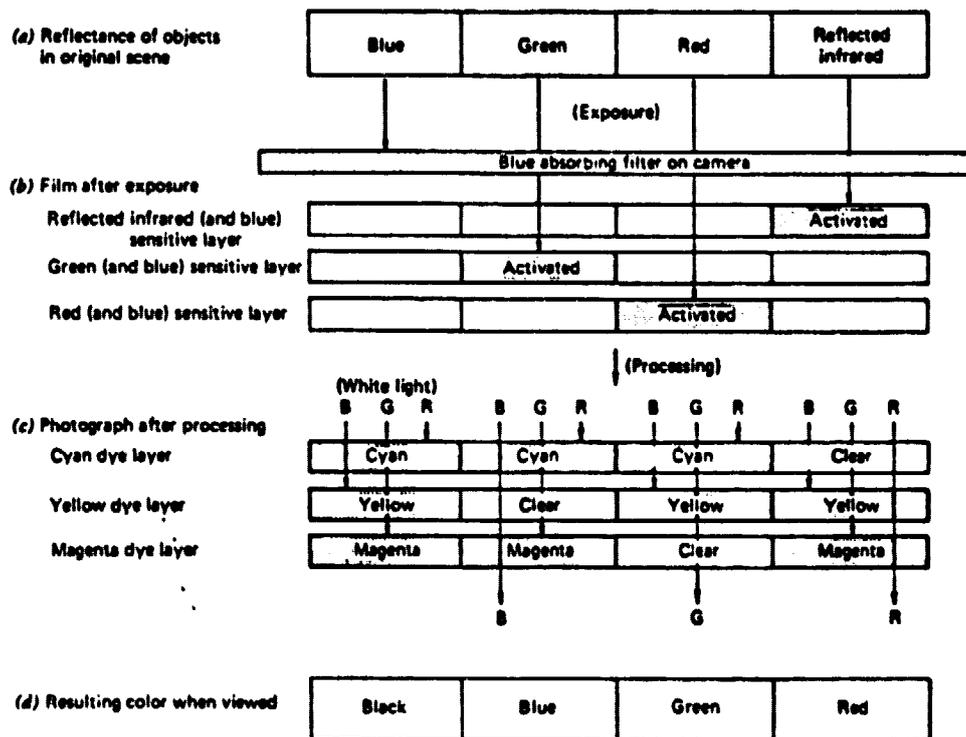
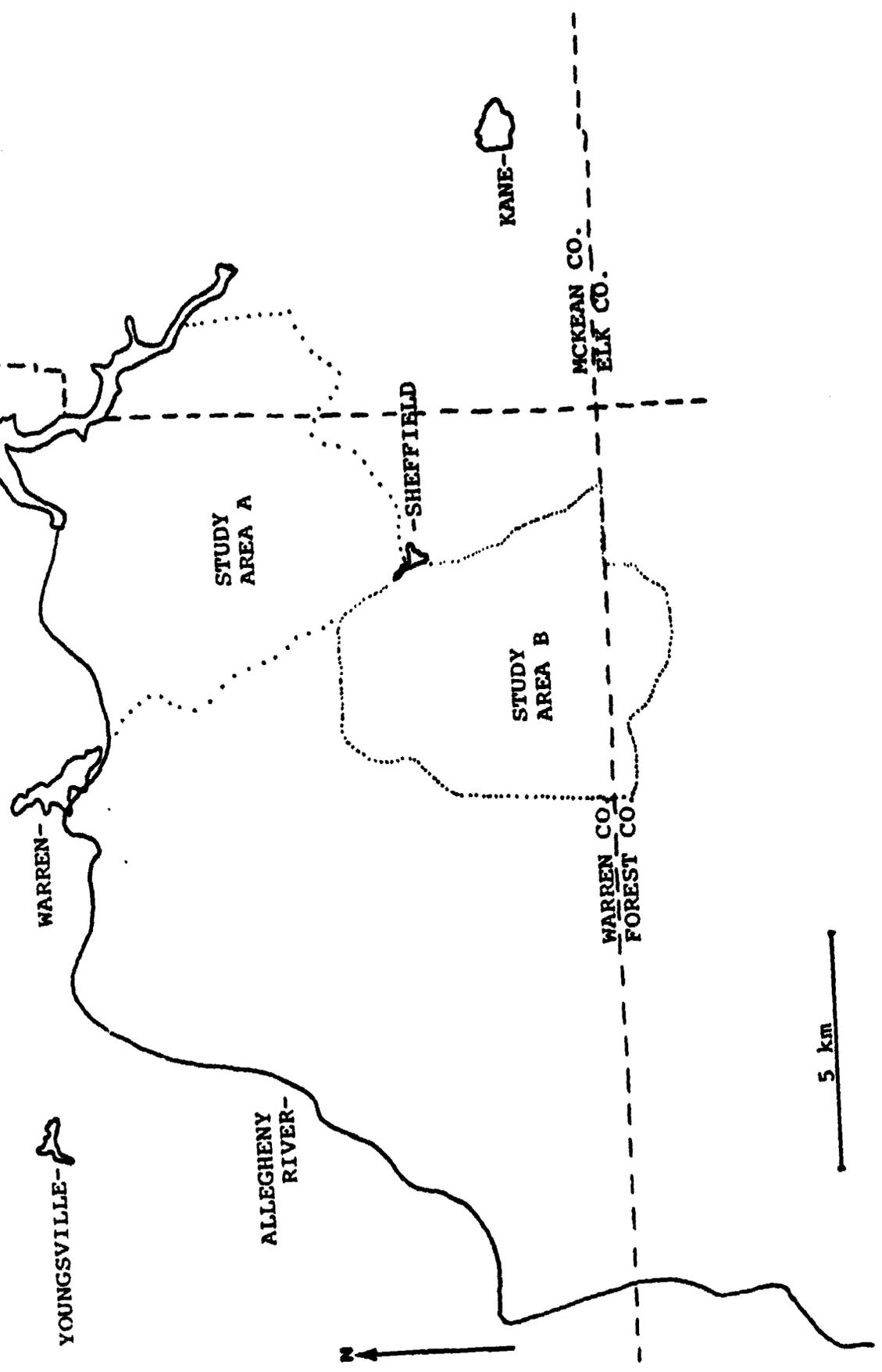


Figure A2: Illustration of color formation on color infrared film.
(From Lillesand and Kiefer, 1979)

APPENDIX B

Location of Study Areas A and B in the Allegheny National Forest, with the location of known clearcuts and the year and acreage of harvest. (Information compiled from compartment maps and records maintained by the Sheffield Ranger District, Allegheny National Forest)

Figure B1: Location of Study Areas A and B in the Allegheny National Forest, Pennsylvania.



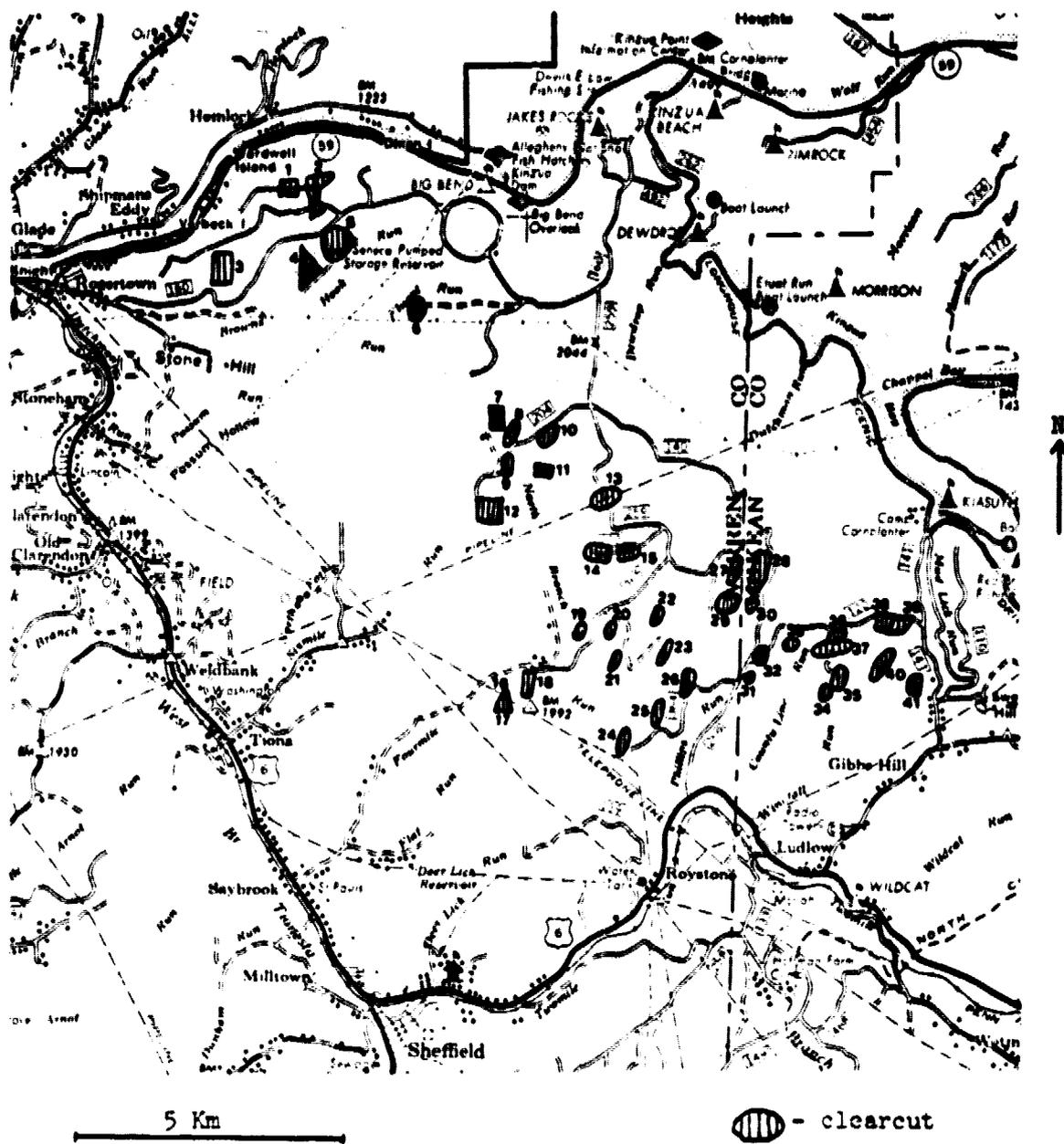


Figure B2: Location of clearcuts in Study Area A. Year of harvest and acreage cut, is recorded in Table B1.

ORIGINAL PAGE IS
OF POOR QUALITY

Table B1: Listing of the year of harvest and the acreage removed for clearcuts in Study Area A, as numbered in Figure B2.

CLEARCUT NUMBER	YEAR	ACRES	CLEARCUT NUMBER	YEAR	ACRES
1	1973	46	22	1968	10
2	1970	60	23	1970	26
3	1964 & 73	55	24	1970	11
4	1973	44	25	1970	13
5	1970	69	26	1970	18
6	1966	22	27	1973	6
7	1968	8	28	1968 & 73	41
8	1968	18	28	1968 & 72	40
9	1968	7	30	1968	7
10	1968	34	31	1966	3
11	1968	12	32	1966	6
12	1972	30	33	1966	5
13	1966	8	34	1973	11
14	1969	48	35	1967	22
15	1969	37	36	1967	8
16	1968	13	37	1967	21
17	1968	21	38	1967	10
18	1968	28	39	1973	9
19	1969	10	40	1973	32
20	1968	13	41	1973	51
21	1968	18			

Official

3 OF 5



181 263 4

UNCL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

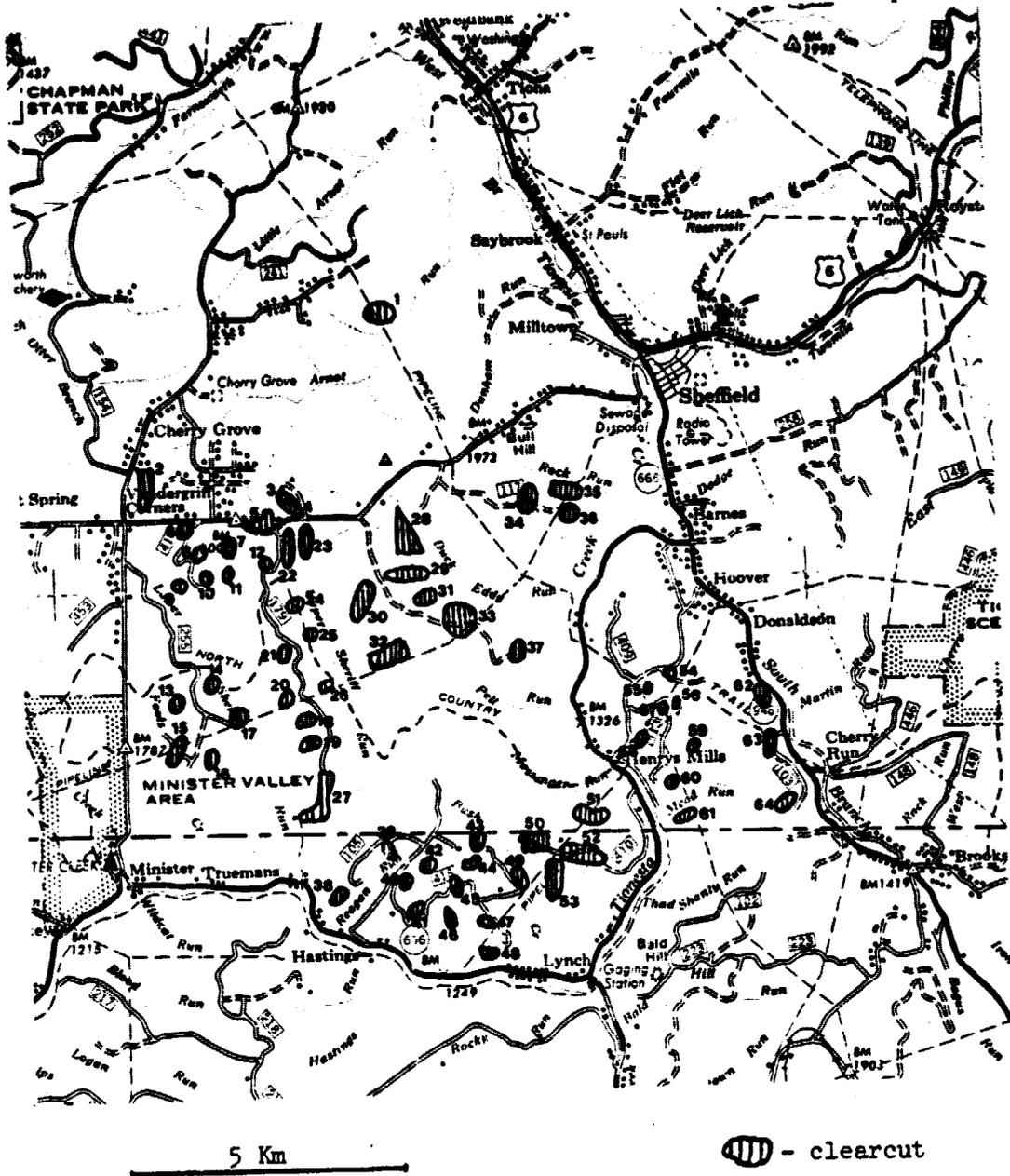


Figure B3: Location of clearcuts in Study Area B. Year of harvest and acreage cut. is recorded in Table B2.

C-3

Table B2: Listing of the year of harvest and the acreage removed for clearcuts in Study Area B, as numbered in Figure B3.

CLEARCUT NUMBER	YEAR	ACRES	CLEARCUT NUMBER	YEAR	ACRES
1	1975	26	33	1976	44
2	1974	27	34	1974	43
3	1972	28	35	1974	44
4	1965	8	36	1966	10
5	1972	37	37	1967	7
6	1968	9	38	1976	29
7	1968	5	39	1966	11
8	1968	4	40	1974	19
9	1968	12	41	1974	21
10	1968	10	42	1974	11
11	1968	6	43	1966	31
12	1962	6	44	1966	17
13	1965	6	45	1966	10
14	1965	5	46	1976	25
15	1966	4	47	1966	10
16	1966	19	48	1966	18
17	1965	10	49	1966	29
18	1973	18	50	1969	42
19	1973	21	51	1969	90
20	1968	5	52	1969	67
21	1968	4	53	1972	54
22	1965	11	54	1967	8
23	1975	42	55	1967	8
24	1965	23	56	1967	5
25	1968	12	57	1967	5
26	1968	5	58	1967	6
27	1974	49	59	1967	11
28	1974	50	60	1967	8
29	1973	50	61	1967	16
30	1974	29	62	1969	30
31	1975	40	63	1969	8
32	1977	40	64	1969	28

APPENDIX C: Comparative Cost of Small Scale Remotely Sensed Data
 Purchased from the EROS Data Center, Sioux Falls,
 South Dakota (August 1980 prices)

SENSOR; PLATFORM	PRODUCT TYPE*	NOMINAL IMAGERY SCALE	COST/IMAGE (\$)
Aircraft	black & white	55.8mm	3
Aircraft	black & white	22.9cm	5
Aircraft	color	55.8mm	10
Aircraft	color	22.9cm	15
Skylab ETC**	black & white	11.4cm	8
Skylab ETC	color	11.4cm	12
Skylab MSC#	black & white	55.8mm	8
Skylab MSC	color	55.8mm	10
Landsat	black & white	55.8mm	8
Landsat	black & white	18.5cm	10
Landsat	CCT##	-----	200

-
- * - all products are positive transparencies
 - ** - Earth Terrain Camera
 - # - Multispectral Camera
 - ## - Computer Compatible Tape

N81-25458

D4

APPENDIX D

Assessment of Potential Industrial Sites
in Essex County, N.Y.

INDUSTRIAL SITE LOCATION

IN ESSEX COUNTY, NEW YORK

Master of Engineering (Civil)
Design Project

Cornell University
Ithaca, New York 14853

Submitted by

Thomas M. Wozny

July 24, 1980

ACKNOWLEDGEMENTS

I wish to express my gratitude to Professor Warren R. Philipson, my academic advisor, whose thoughtful, active guidance was essential to the completion of this project. His support and patience saw me through my graduate studies. My thanks also go to Professor Ta Liang, whose courses kindled my interest in the field of environmental evaluation, and whose vast knowledge is surpassed only by his kindness.

I am deeply indebted to my friends, William Teng and William Hafker, who urged me on in dark moments. Their friendship is invaluable.

Lastly, to my wife, Kathryn, who spent many late nights typing, and who endured my ill temper for several months, I am eternally grateful.

CONTENTS

	<u>page</u>
INTRODUCTION	1
PROCEDURE	2
I. Elimination of Certain Lands from Consideration	3
A. State Owned Lands	3
B. Steep Lands and High Elevations	4
C. Further Considerations	5
II. Site Selection and Evaluation Criteria	9
A. Bedrock and Soil Cover	9
B. Water Supply	11
C. Accessibility	13
D. Site Preparation Required	13
E. Size of Site	13
F. Current Land Uses	14
EVALUATION OF THE DATA SOURCES	15
SMALL SCALE AERIAL PHOTOGRAPHS	15
OTHER SOURCES	
Medium Scale Aerial Photographs	19
Soil Surveys and Maps	19
ANALYSES OF THE SITES	21
COMPARISON OF THE SITES	128
OVERLAY 1: State Owned Lands	130,132
OVERLAY 2: Steep Land	131,132
BIBLIOGRAPHY	133

INTRODUCTION

In an attempt to improve its employment situation and overall economic base, Essex County, New York is seeking to attract industries. The County Planning Office wishes to identify lands within the county that might be suitable as industrial sites.

Essex is a county of great, natural beauty, located entirely within the boundaries of the Adirondack Park. As such, the county planning office has a moral as well as legal obligation to preserve the environmental quality of the area. For a tract of land to become an industrial site it must, in addition to satisfying the engineering and economic requirements, be selected so as to generate a minimal amount of environmental disruption.

It is not the focus of this Design Project to address the question of siting industries within the already developed towns and hamlets or alongside of the highways that cross the county. It is assumed that the potential for development of lands within these developed areas is fairly well known. Rather, this project attempts to locate and evaluate, using remote sensing methods, possible sites that are not readily observable from the towns and roadways. In addition to finding sites that might possibly be overlooked by developers, its objective is to locate sites that will not disturb the scenic beauty of the county.

This report offers a region by region discussion of the environmental limitations to industrial development and recommends specific locations for further investigation as possible industrial sites.

PROCEDURE

In order to systematically search through the County's 1826 sq. mi. (4,730 sq. km.) of land for suitable sites, it was necessary to perform the search in several steps. Different characteristics of the land were isolated and evaluated with the purpose of either eliminating a particular tract from, or giving it further, consideration.

I. Elimination of Certain Lands From Consideration

Certain lands were eliminated from consideration for any future development: (A) State-owned land and (B) land too steep to build upon at a reasonable expense without severe environmental impact. If it was determined that a parcel was State-owned or if it had a slope in excess of 15%, development of it was ruled out.

A. STATE OWNED LAND

Essex County lies entirely within the boundaries of the Adirondack Park and as such is bound by the provisions of the Adirondack Park Agency Act. The purpose of the Act was to maintain the wilderness character of the Park for all time and to set strict guidelines for development of any type.

Article XIV, Section I of the New York State Constitution declares that, "The lands of the state, now owned or hereafter acquired, constitut'ng the forest preserve as now fixed by law, shall be forever kept as wild forest lands. They shall not be leased, sold or exchanged, or be taken by any corporation, public, or private, nor shall the timber thereon be sold, removed or destroyed."¹ (emphasis added). This became effective January 1, 1895.

The forest preserve provides watershed protection for a large part of the state as well as forest recreation. In 1883, 750,000 acres of state-owned lands were withdrawn from sale by the Legislature. The State has

¹ Murtha, P.A. and McNeil, R.J., "The Forest Preserve," Current Topics in Conservation, Series II, No. 7, Cornell University, Ithaca, NY 1966.

continued to add land as it became available through gift, purchase or tax delinquency. The current total is over 2.6 million acres, scattered among 16 "Forest Preserve Counties," one of which is Essex.

The clear directive of the State Legislature and the State Constitution should dissuade any consideration of the state-owned lands as possibilities for future industrial development. Accordingly, Overlay 1 was prepared to delineate those lands that were state-owned as of April 1, 1979. The information on the overlay was obtained from the "Adirondack Park Land Use and Development Plan Map," prepared by the Adirondack Park Agency. The pertinent areas were brought, with the aid of a Zoom Transfer Scope, to the common scale of 1:126,000 used in this report. A copy of overlay 1 is in the back cover pocket; a reduced copy overlies figure 21 (p.132).

For the purposes of site selection, then, these lands will not be considered.

B. STEEP LANDS AND HIGH ELEVATIONS

The Adirondack Park Agency Guidelines² urge a limitation of development to slopes less than 15%. It further restricts roadways to slopes measuring less than 12% over a 150 ft. length.

Areas with slopes exceeding approximately 15% were located on the 16 U.S. Geological Survey 15 minute topographic sheets (scale 1:62,500) which cover the County, using the high-altitude photographs for further refinement. Each topographic sheet was scanned and the spacing between contour and intervals measured. Those areas having slopes measuring more

² Development in the Adirondack Park, The Adirondack Park Agency, Ray Brook, NY, April, 1977, pp. 17-1 and 25-2.

than 15%--an elevation change of 150 ft. over a 1000 ft. distance (approximately five 20 ft. contour intervals per 1/8 inch on the map)-- were outlined. These areas were then transferred to an overlay to the county base map (scale 1:126,000), with the aid of the Zoom Transfer Scope. Overlay 2 represents the final compilation of the steep lands gathered from the 16 quadrangles. A copy is located in the back pocket, with a reduced copy on p. 132 (figure 21).

Also among the areas excluded on Overlay 2 are those with elevations greater than 2500 ft. (0.76 km.), whether or not their local slopes are also greater than 15%. This is intended to preserve the "fragile ecosystems at higher elevations" as outlined by the APA Guidelines.³ Any type of development activity at such elevations is strongly discouraged and will be eliminated from consideration here.

The two principal overlays each show areas of land that can be fairly safely ruled out for consideration. Viewed jointly, these two constraints eliminate much of the land in the county. Site location efforts can then focus exclusively on the remaining areas.

C. FURTHER CONSIDERATIONS

There are areas within the County with suitable physical characteristics for industrial development (level slope, private ownership, good soil behavior, and ease of access) for which it may be desirable, or even legally required, to restrict development for a variety of reasons. Many restrictions are described in the Adirondack Park Agency's guidelines.⁴ Included among

³ Ibid., p. 6-1.

⁴ "Development in the Adirondack Park," Adirondack Park Agency, Ray Brook, New York, April, 1977.

the existing land uses that are desirable to protect are: agriculture, aesthetics of travel corridors,⁵ scenic vistas,⁶ recreation,⁷ shorelines,⁸ hamlets,⁹ and hamlet approaches.¹⁰

These areas are described in the introductory notes for each area. It will be left to the judgement of the user of this report whether to pursue development in these areas.

1. Agriculture

"Less than 8% of the privately owned land in the Adirondack Park is used today (1974) for farming of any kind..."¹¹ Agriculture is considered an extremely valuable asset to Essex County. Conversion of prime agricultural land to other uses is discouraged. Land used for agriculture will be avoided in this site location study, unless it appears that the farming of a particular tract is in the process of abandonment, perhaps because of soil infertility. In these cases, the sites will be listed for future reference but should still be avoided if the agriculture might be rejuvenated.

⁵ Ibid., p. 2C-1.

⁶ Ibid., p. 2B-1.

⁷ Ibid., p. 10B-1.

⁸ Ibid., p. 11-1.

⁹ Ibid., p. 2A-2.

¹⁰ Ibid., p. 2A-2.

¹¹ Hyde, Floy S., Adirondack Forests, Fields, and Mines, Lakemont, N.Y., North Country Books, 1974, p.142.

2. Travel Corridors

By the Adirondack Park Agency's definition, "A travel corridor is that strip of land constituting the roadbed and right of way for state and interstate highways in the Adirondack Park and those state lands immediately adjacent to and visible from these highways." ¹² "The lands adjacent to these highways are the most visible to the traveling public and frequently determine the image and entire atmosphere of the Park for many visitors. In addition, due to the heavily forested character of the Park, scenic vistas from these travel corridors are relatively rare and their protection and enhancement is important." ¹³

Within Essex County, the following roads have been designated as "travel corridors."

I81	NYS 28N
NYS 3	73
9	86
9N	373
22	431
	903

Development alongside or in the view of these corridors is discouraged.

As evidenced by the state's designation of spots of several of the county roads as "scenic vistas" (below), there has been an intent expressed by the legislature to consider roads in addition to interstate and state highways as worthy of protection. The same care should be exercised when planning a site near one of the county roads as would be given to a state highway.

¹² "Adirondack Park State Land Master Plan," Adirondack Park Agency, June 1, 1972, p. 18.

¹³ Ibid., p. 19.

3. Scenic Vistas

There are ten areas in the county that have been designated by the Adirondack Park Agency as "scenic vistas," for which the natural beauty of the spots must be preserved.¹⁴ They are described for each area.

4. Adjacent Land Use

Not only must one consider the use to which land is being put on the immediate tract of land being viewed as a possible site, but the activities on adjacent and nearby lands must also be reckoned with. Such land uses are discussed for each site described below.

In addition to the aforementioned land types that were ruled out for various environmental or social reasons, water bodies, wetlands, and active flood plains were not considered as having potential for industrial development.

II. Site Selection and Evaluation Criteria

The above considerations rule out approximately three-quarters of the land in Essex County. The remainder of the lands in the county were evaluated for their potentials as industrial sites based upon the following criteria.

A. Bedrock and Soil Cover¹⁵

Extremely hard, crystalline rock underlies almost all of Essex County. This bedrock, which is made up of anorthosites, granites, syenites, and gneisses, is quite resistant to erosion and accounts for the steep, rugged terrain of most of the County. The eastern margin along Lake Champlain has a few areas underlain by limestone and sandstone. All of these bedrock types are very capable of supporting structures, but excavation in them could be quite expensive.

The entire area was glaciated some 10-20,000 years ago. This profoundly shaped the surface of the land, leaving deposits of irregular depth and composition spread over the bedrock. Most of the area was covered with till, a densely-compacted mixture of stones and boulders in a matrix of soils of varying textures. The soils that developed in till are capable of supporting structures, but the virtual randomness of boulder inclusions makes the expense of

¹⁵ General references: Kemp, James Furman, and Ruedeman, Rudolf, Geology of the Elizabethtown and Port Henry Quadrangles, New York State Museum Bulletin, No. 138, Albany, University of the State of New York, 1910; and Merrill, J.H. and Kemp, J.F., The Geology of the Moriah and Westport Townships, Essex County, N.Y., New York State Museum Bulletin, No. 138, Albany, University of the State of New York, 1895.

excavation unpredictable. The sandy till soils are generally well drained, but the finer grained soils might cause problems with wetness, shrinkage and swelling, and frost susceptibility. A few of the till soils have developed fragipans at depths of several feet. This forms a barrier to downward water percolation that might result in drainage problems in some areas.

Several valley areas filled with outwash as the glaciers melted. Soils that formed in outwash are generally coarse textured, with excellent drainage and good strength. Outwash soils are droughty and usually acidic and so make fairly poor agricultural soils. Streams have cut into the outwash-filled valleys leaving the outwash soils as terraces along the valley walls. As such the water tables are usually quite low. They are among the most suitable soils for development.

Much of the soil cover in the eastern portion of the county was formed in lakebed material. Clay soils produced in this manner have the best agricultural potential in the region and are among the most problematic for construction. On even gentle slopes they are unstable; shear strengths and bearing capacities are generally very low; they have a high susceptibility to frost action, shrinkage, and swelling; their fine texture gives them low permeability, often leading to severe drainage problems and septic tank failure. These soils are best avoided.

Along the rivers and some streams are alluvial soils. These soils are recently formed, highly erodible, have high water tables, and are flood prone. Development in these areas should also be avoided.

B. Water Supply

a) Ground Water

The soils which were formed in glacial outwash or sandy lacustrine materials are generally coarse textured (sands and gravels) and quite porous and permeable to ground water. As such they are often capable of producing water from wells at rates as high as a few hundred gallons per minute.¹⁶ Soils of this type found in Essex Co. are of the Windsor and Colton Associations.

Some of the sandy, till-derived soils, such as those of the Hermon Association are also quite permeable and capable of producing fairly large volumes of water (less than 100 g.p.m.).

The lakelaid soils that cover much of the eastern portion of the county are generally poor aquifers. They are clays for the most part, having very low permeabilities. Included among these soils are the Vergennes-Kingsbury, Elmwood-Swanton, and Kingsbury-Covington Associations.

With the exception of some areas of limestone, sandstone, and shale along the eastern margin of the county, most of the bedrock is crystalline. The crystalline formations are extremely impervious to water and, as such, ground water is found only in rock fractures or at the contact between the bedrock and the overlying soils. At some locations crystalline rocks will yield up to 35 g.p.m.¹⁷

¹⁶ Giese, G.L. and Hobba, W.A., Jr., Water Resources of the Champlain-Upper Hudson Basins in New York State, Albany, N.Y., New York State Office of Planning Coordination, 1970.

¹⁷ Ibid., Plate 1.

The carbonate and sedimentary rocks that exist beneath areas in the Ticonderoga, Port Henry, and Willsboro Quadrangles are somewhat permeable to ground water. They are capable of producing as much as 300 g.p.m.¹⁸ The highest rates recorded from wells in Essex County producing from the rocks, however, have been only around 15 g.p.m.¹⁹

The aquifers most often tapped in the county and which have been the most productive are the unconsolidated sands and gravels. Production rates from wells in the materials have been recorded as high as 105 g.p.m.²⁰ The high permeability of these soils makes them susceptible to pollution. Industrial development in such areas must be done with attention paid to this potential hazard.

b) Surface Water

Essex County does not lack surface water; there are hundreds of lakes, ponds, rivers, and streams within its boundaries. Many of the sites are near streams or ponds. Streamflow records are available from the New York State Water Resources Commission and are included in some of the site descriptions below.²¹

18 Ibid., Plate 1.

19 Ibid., pp. 112-115.

20 Ibid., p. 113

21 Ibid., Plate 2.

C. Accessibility

It is clear that a site is of little value if it is inaccessible. Much of the land in Essex County is, in fact, inaccessible, for all practical purposes. However, those lands happen to be among those previously ruled out as being state-owned or steep. No site that was given consideration was ruled out as being inaccessible. Sites were merely rated in terms of their relative accessibilities.

D. Site Preparation Required

Among the features evaluated to estimate the amount of effort required to build upon a particular site were: the local relief, density of tree cover, distance from an access road, and any existing land uses, such as extraction operations ongoing at some sites, that might interfere with site development. These characteristics of the sites were determined from the airphotos.

E. Size of Site

The boundaries of each of the sites are defined by one or more of the following variables: the terrain, the soil depth, the water table, and the adjacent land uses.

Many sites are on hillsides, with the upland border defined by either the appearance of bedrock close to the surface or by slopes exceeding a practical angle (15%) to build upon. Some of the same sites, as well as others, are effectively terminated on their lower sides by wet or potentially wet soil conditions. Many are bounded

by alluvial soils, by streams, ponds, or swamps. Boundaries defined by such criteria have an inherent degree of flexibility in that they can often be extended at some expense. The boundaries delineated on the maps are based upon estimations of where any of these problems would first be encountered.

Boundaries based upon the surrounding land uses are often less flexible than those imposed by nature. As discussed above, the likelihood of the sale of state-owned land is small. A few sites have at least one side terminated in this manner. There are a multitude of existing adjacent land uses that present limits to site sizes.

The feasible boundaries were determined by airphoto interpretation and mapped onto overlays to the U.S.G.S. Topographic Maps. Areas were then estimated using a grid drawn to the map scale. Calculations were done in English units, to conform with the map, and converted to metric units.

F. Current Land Use

The ground cover or the use to which the potential site was being put at the time the small scale photographs were obtained (June 25, 1979) is described for each site. Also considered, and discussed in the report, are the activities on the lands nearby each of the sites. These are viewed with concern for possible disruption caused by industrial development.

EVALUATION OF THE DATA SOURCES

SMALL SCALE AERIAL PHOTOGRAPHS

High altitude, color infrared aerial photographs (transparencies, scale approximately 1:120,000) were taken by NASA on June 25, 1979. The photographs cover the entire county and some surrounding areas with stereoscopic coverage. They proved to be the most useful source of information on a broad range of physical and land-use parameters. As such, the interpretation of these photographs represented the lion's share of the analysis.

The relatively small scale of the coverage yielded a synoptic view of large areas. Only twenty-seven 9 in. by 9 in. photographs were needed to view the entire county. This made the task of evaluating the almost 2,000 sq. mi. (4700 sq. km) area considerably easier. The stereoscopic coverage allowed for viewing the county in three dimensions, which was indispensable in such a rugged area. Each stereomodel covered a ground area of approximately 200 sq. mi. (518 sq. km). The high resolution of the film allowed it to be viewed at higher magnification without intolerable loss of detail. This fact allowed the same film to be used for the dual purpose of scanning large areas for sites and then analyzing those sites in greater detail. The elimination of the need for repeatedly switching to a variety of data sources speeded up the process considerably.

The high altitude photographs provided much of the information on the following site evaluation criteria:

TERRAIN VARIABLES - Slope - Although photogrammetric methods could have been employed to measure the slopes directly from the

photographs, this was not done. Instead, they were viewed qualitatively, with the more accurate quantitative slope measurements made on the topographic maps. After some practice, however, it was possible to make judgments distinguishing between areas that "looked too steep" to build upon and those that warranted further study.

Soils - While complete characterization of the soil types was not possible using the photographs alone, it was possible to approximately delineate areal units having homogeneous soil properties. This was especially true in cases where the properties of adjacent soils were markedly different, as at terrace/upland, wetland/dry-land, and flood plain/upland boundaries. Bare rock was usually easily distinguishable from soil. To some extent it was possible to infer such soil properties as the relative particle grain sizes based on photographic tones: light tones indicating dry, well-drained (coarse) soils, and dark tones indicating wetter, fine-grained soils.

Such distinctions have great value in predicting the behavior of a soil.

Water bodies - The very dark response of water on infrared-sensitive film makes such film excellent for locating streams and bodies of water against the brighter backgrounds of soil and rock.

Size of sites - The actual measurements of the sizes of the sites were made on the topographic maps, benefiting from their rectified geometries and uniform scale (unlike that of the photographs, which varies with both relief and tilt displacement, as well as with distance from the nadir point). However, the site boundaries that were drawn onto the topographic map overlays were interpreted from the photographs, based upon the recognizable features discussed above. In some cases, the interpreted positions of those boundary-defining features were in agreement with their mapped positions. Many more times, however, they were at odds, especially with respect to the locations of wetlands. In either case, the photographically inferred boundaries were used and then positioned in relation to points common to both photo and map that were in agreement.

LAND USE - A variety of land use patterns were recognizable, many of which served to update or qualify the existing maps. Land uses recognized included: roads and railroad tracks, buildings, mining operations and gravel pits, agricultural patterns, campsites, ski slopes, golf courses, boat launches, historic sites, and other hamlet-related features.

VEGETATION COVER - The density of tree cover can be seen and some discrimination among species made. It was not necessary to identify tree types per se, but changes in tree type and density from area to area often coincided with changes in ground conditions such as in soil moisture and depth to bedrock.

VISIBILITY OF SITES - The stereomodal allowed for a determination of "viewshed"--the area that can be seen--from any given point in the county. Thus, the limits of visibility along travel corridors and from specific vantage points could be mapped. Alternatively, by working back from potential sites, it was possible to determine from where they might be seen.

ACCESSIBILITY OF SITES - Proximity to towns and travel corridors can be estimated from the photos. This parameter was, however, measured on the topographic maps. Approximate grades that access roads would have to traverse can also be determined. Any unusual features or potential problems,

such as wetlands, rock outcrops, or water bodies to cross, can usually be identified directly on the photos.

OTHER SOURCES

Medium Scale Aerial Photographs

Aerial coverage of the county was also available in panchromatic, medium scale (1:24,000) photography, obtained in April, 1968. While these contact prints served as a useful complement to the high altitude photos, the quality of the latter was sufficiently good that when viewed under high magnification its resolution was virtually as good as the larger scale black and white photos. The primary role of the black and white photographs was to give "a second opinion" for particular areas that were not clearly resolved on the high altitude photos.

Soil Surveys and Maps

The primary source of information about the soils likely to be encountered on a particular site was the General Soil Map of Essex County (1:62,500), prepared for the Adirondack Park Agency by the U.S. Department of Agriculture in cooperation with the Cornell University Agricultural Experiment Station (1975). The expressed accuracy of this map is that 85% of the soils in any area delineated as a homogeneous soil association unit must conform to the range of physical properties attributed to that soil association. The resolution of this identification scheme extends to parcels of land as small as 40 acres.

This map then was interpreted as giving only a generalized, averaged description of the soils that could be expected to be found on a given site.

The airphotos supplied additional information, which further refined the boundaries of the homogeneous units. Also located in the photos were some areas that are likely to be poorly drained, that did not appear on the soils map.

The soil characterizations in this report should be used only as a starting point for investigation. Before any site is seriously considered, a thorough ground survey of the soil should be undertaken.

ANALYSES OF THE SITES

Land which had not been ruled out for development for one or another of the aforementioned reasons was evaluated and is discussed here. This section is organized in relation to the U.S.G.S. 15-minute topographic quadrangles (1:62,500) which cover the county. Thirty eight potential sites were identified and are discussed here.

Figure 1 shows the locations of the sites in relation to the major transportation corridors of the county. The grid corresponds to the topographic sheets, which are abbreviated as follows:

Saranac Lake	SL
Lake Placid	LP
AuSable Forks	AU
Willsboro	W
Santanoni	SA
Mount Marcy	MM
Elizabethtown	E
Port Henry	PH
Newcomb	N
Schroon Lake	SC
Paradox Lake	PL
Ticonderoga	T

Because of the size of the county and its diversity of terrain and land use patterns, each quadrangle is discussed separately. Within each quadrangle as many as seven sites are identified.

SARANAC LAKE QUADRANGLE

Most of the land within the Essex County portion of this quadrangle is state-owned (overlay 1). Included among the remaining possibly usable land are the following:

- A) The corridor along NYS Route 3 between the Villages of Saranac Lake and Bloomingdale. The soils along this relatively flat corridor are of the Windsor and Rumney-Saco Associations, which developed in outwash and alluvium, respectively.

The Rumney-Saco soils which comprise the flood plain of the Saranac River are unsuitable for development. They are generally quite swampy and flood-prone. The Windsor soil areas, which occupy the sloping terraces along the western side of the highway have characteristics that make them more suitable for development. There are a few sand and gravel excavations, which when depleted might become suitable industrial sites.

The advantage of this site is its accessibility, being adjacent to the highway and having much of the tree cover cleared away. Route 3 connects Saranac and Tupper Lakes with Plattsburgh and the Northway and is a "travel corridor" designated by the APA. As such, care should be taken to preserve (or, in this case, restore) the appearances of the corridor, which is likely to be used by many visitors and residents.

SL1

LOCATION: Two miles (3.2 km.) southwest of the Town of Lake Placid on the Averyville Rd., near Alford Pond (Figure 2).

EXISTING LAND USE/

GROUND COVER: The tract is partially wooded and partially cleared.

It appears that at one time, it had been cleared for agricultural use, which was later discontinued. The surrounding land uses are presently agricultural.

SOIL: The site is located on a small till plain. The till-derived soil appears deep and well-drained. According to the General Soils Map it is of the Becket-Peru Association, a medium-to-coarse grained loam, capable of supporting buildings, but also suitable for agriculture. Becket-Peru soils generally have fragipans which could inhibit water percolation and cause drainage problems at depths of a meter or more.

The northern end of the tract is bounded by a stream with adjacent soils that appear wet on the photographs. This would limit construction in that direction.

SIZE: The amount of visibly dry land currently unused for agriculture is approximately 3.3×10^6 sq. ft. (3.1×10^5 sq. m.).

B) The western approach to the village of Lake Placid may be suitable for development. The soils are of the Hermon Association, which is a sloping, very bouldery till, with fairly good construction potential. However, this is a scenic route and development should proceed with great care.

The same may be said for the privately-owned lands in the hamlet of Ray Brook. Most of this area is on Windsor outwash soils.

Recommended for further investigation for industrial development are the following locations, which lie outside of the highway corridors.

Figure 2

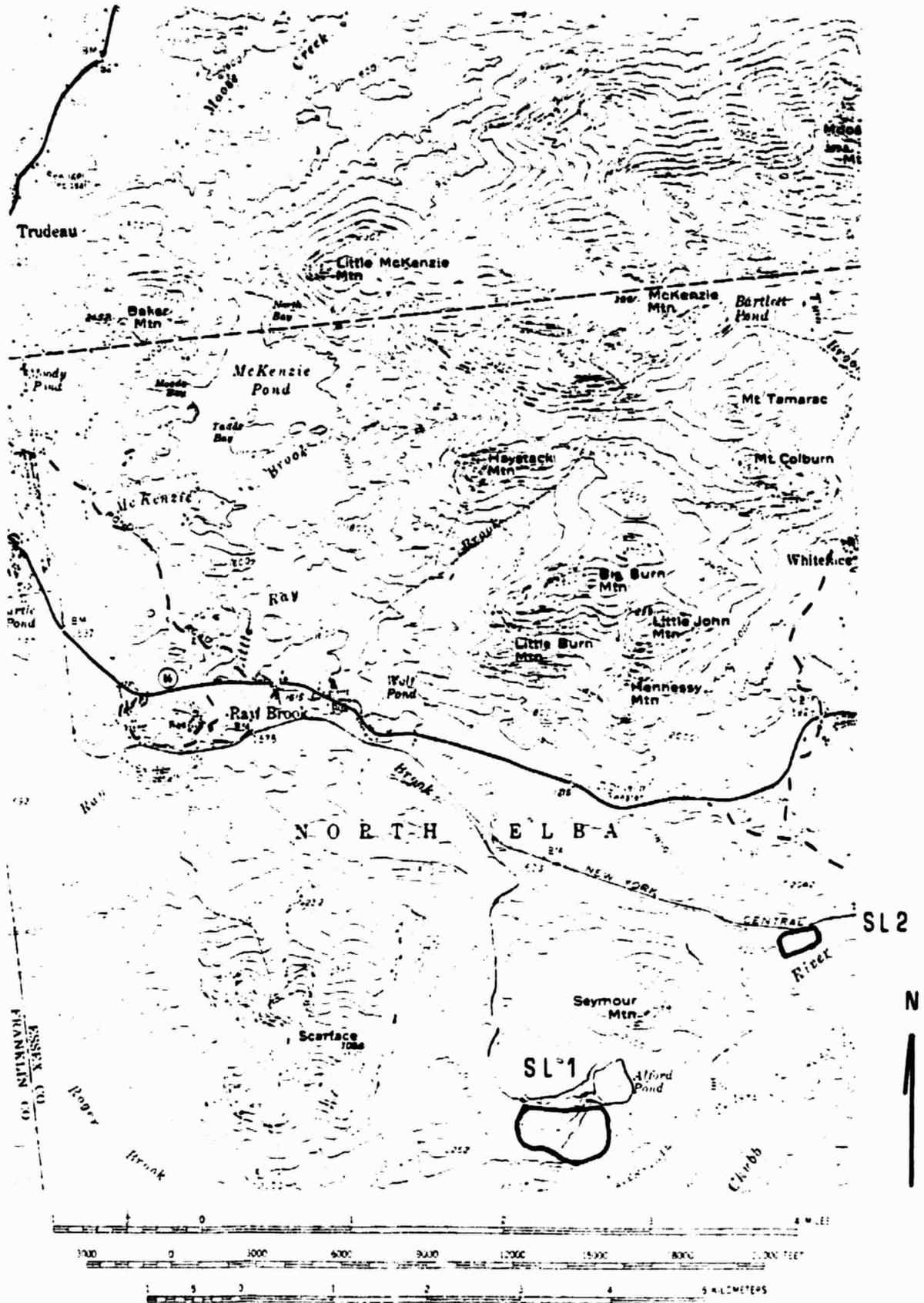
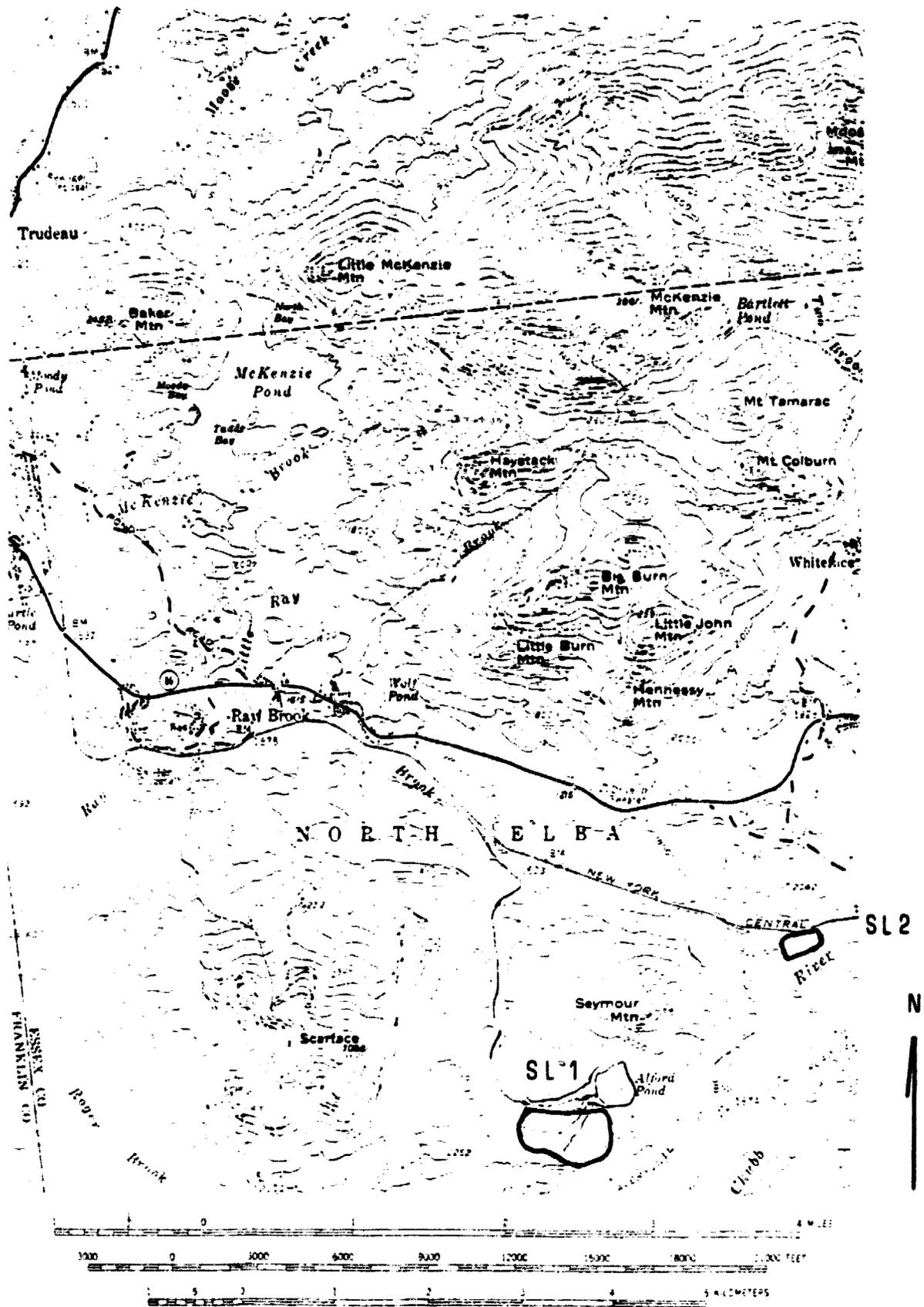


Figure 2



ORIGINAL PAGE IS OF POOR QUALITY

WATER: Alford Pond is a source. Ground water may be limited by the till-derived soil. The crystalline bedrock is also impervious and unlikely to act as an aquifer.

ACCESSIBILITY: Very good via the Averyville Rd. No steep grades are required for access driveways. It is close to Lake Placid.

SITE PREPARATION REQUIRED: Very little--the land is partially cleared, the grades are not steep, and it is not far from the road.

ADVANTAGES: It is a large site with room for expansion. Much of the tree cover has already been removed. The land's use for agriculture has apparently been abandoned. It is hidden from view from the town and highways, with access via a little-used road.

DISADVANTAGES: Construction would possibly have negative effects on the adjacent agriculture. Also, the soil behavior is only fair with respect to construction. Drainage might be a problem, particularly along the northern edge of the site.

SL2

LOCATION: One-half mile west of the village of Lake Placid, adjacent to the N.Y. Central Railroad's tracks. (Figure 2.)

EXISTING LAND USE/

GROUND COVER: The immediate site and surrounding areas are wooded. Land between the site and the town appears to be in commercial or industrial use.

SOIL: BECKET PERU ASSOCIATION - A deep, medium-to-coarse textured loamy soil with a fragipan, derived from glacial till. Soil strength is fair and capable of supporting buildings, but the water table appears to be fairly high leading to possible problems. Permeability may also be poor, so drainage may be very slow and septic tanks may not function. Topsoil derived from this soil association is often suitable for agriculture.

This site has a low topographic position and is surrounded by slightly lower, wet ground. Any rise in the level of the adjacent wetlands could cause flooding.

SIZE: Approximately 1.2×10^6 sq. ft. (0.11 sq. km.)

WATER: The water table may be quite high near this site. The Chubb River, which passes by the site, may be a source of surface water.

ACCESSIBILITY: It is fairly close to the Averyville and Old Military Roads. A driveway could be constructed to either. The N.Y. Central Railroad passes by the site.

SITE PREPARATION REQUIRED: It is wooded on a gentle slope. The lower edge of the site might become seasonally wet.

ADVANTAGES: It is close to town, yet hidden from view. It would not disrupt any agriculture. It is relatively level.

DISADVANTAGES: It may be wet. Adjacent ground was visibly wet as seen on the photographs. This effectively limits the size of the site. The soil's engineering characteristics are only fair.

SL3

LOCATION: Two miles north of the village of Saranac Lake, midway between
NYS Routes 86 and 3, at the southern base of Brewster Mountain.
(Figure 3.)

EXISTING LAND USE/

GROUND COVER: Wooded. Across the valley is a school, a residential area,
and the Mt. Pisgah Ski Slopes. Wetlands border it on the
lowland side and steeper slopes on the upland side.

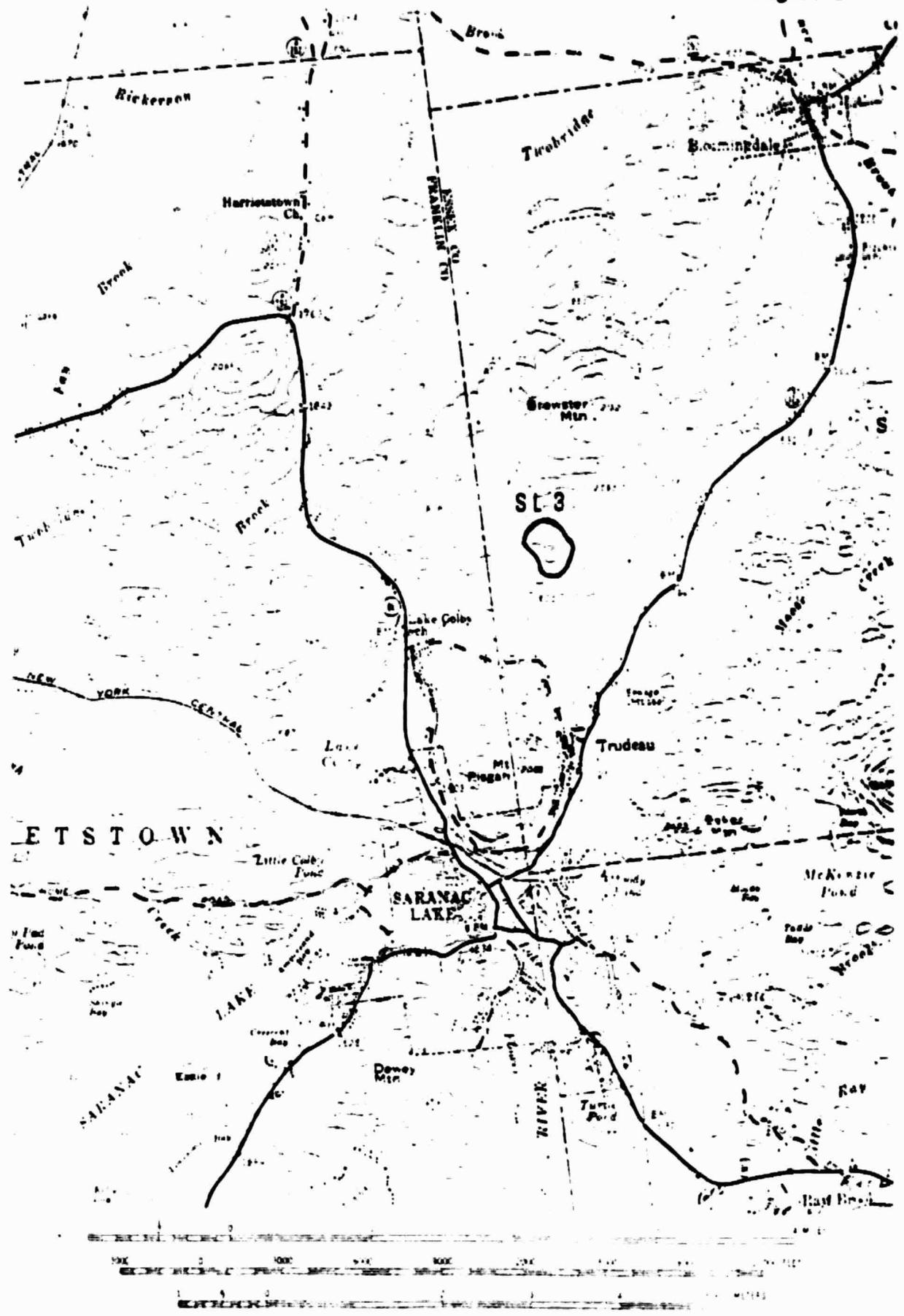
SOIL: BECKET PERU ASSOCIATION - A deep, medium-to-coarse textured loamy
soil with a fragipan, derived from glacial till. Soil strength
is fair and capable of supporting buildings, but the water
table may be high at the lower end of the site. Permeability
and the resulting drainage may be poor, so septic tanks
may not function. Topsoil derived from this soil association
is often suitable for agriculture.

SIZE: Approximately 2.7×10^6 sq. ft. (0.25 sq. km.)

WATER: It is close to the Saranac River and bordered by wetlands.

ACCESSIBILITY: It is roughly a mile from both 86 and 3. A driveway would
have to skirt the wetlands.

Figure 3



SITE PREPARATION REQUIRED: Trees would have to be cleared. It is on a relatively gentle slope.

ADVANTAGES: It is hidden from the highways.

DISADVANTAGES: It may be visible from the side slopes across the valley. It is a mile from the highway. The lower edge of the site is clearly a wetland.

LAKE PLACID QUADRANGLE

Most of the land in this quadrangle is too steep to build upon (overlay 2). The land in the western half is almost exclusively state-owned, with the exception of the Village of Lake Placid.

Development of the privately-owned lands on the eastern edge of Lake Placid is not limited by the soil, which is primarily the Hermon Association. There are occasional wetlands in low-lying areas. The primary restraint is the designation of area as a scenic vista by the State. Any construction here must be unobtrusive.

Areas immediately west and south of Wilmington have soils that are suitable for development. The slopes are visible from the highways (86 & 12), which lead to Whiteface Mountain and "North Pole," very popular tourist attractions.

The prime areas for development in this quadrangle are located close to the Keene-Wilmington corridor.

LOCATION: One mile (1.6 km.) northwest of the Village of Keene on Limekiln Rd. (Figure 4.)

EXISTING LAND USE/

GROUND COVER: Open excavations, possibly a san. and gravel pit.

Adjacent lands are wooded.

SOIL: This site is located on a terrace on the side of a large hill.

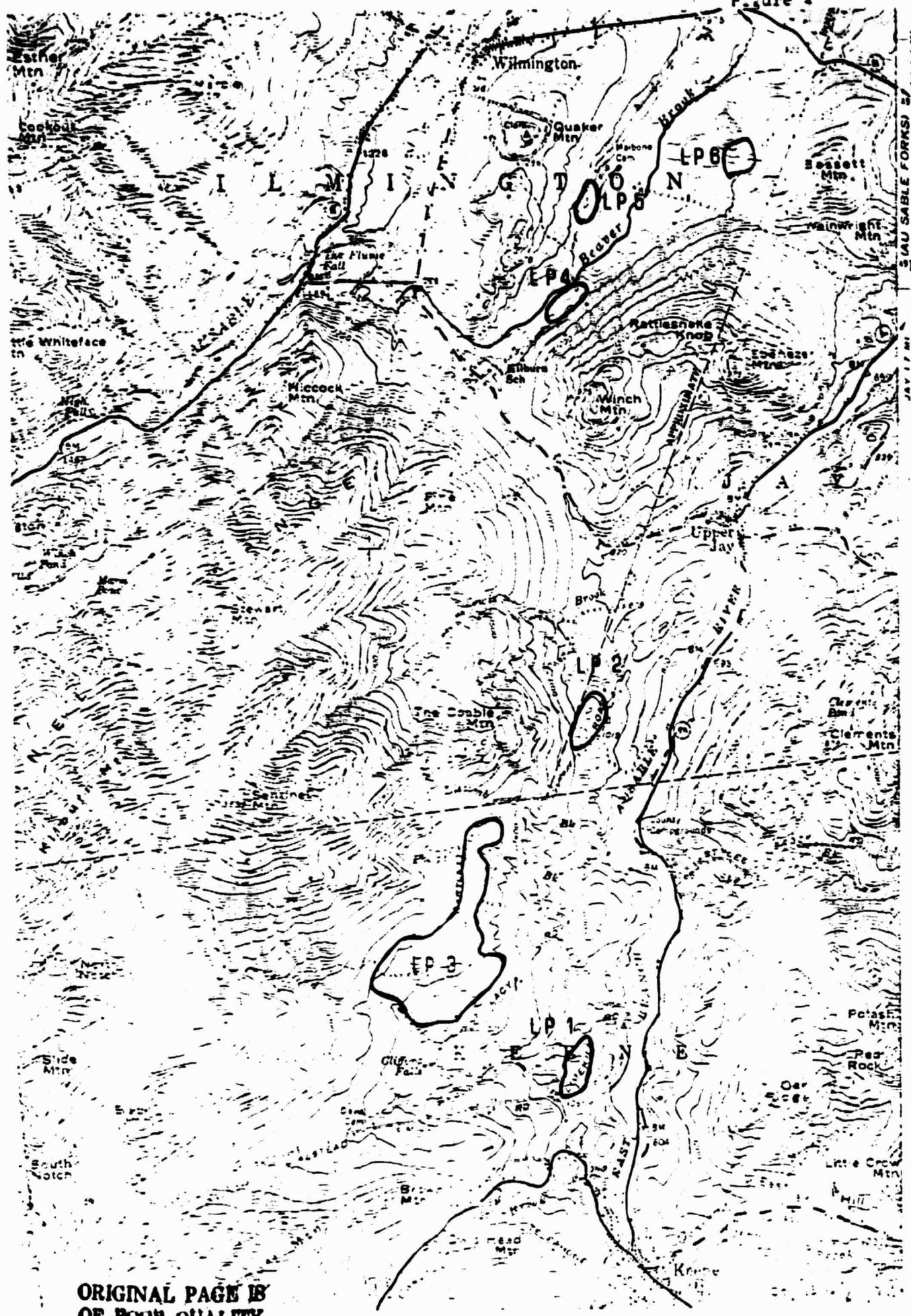
The soil appears to be deep and well-drained and probably formed in glacial outwash. Soils of this type in this area are of the very coarse grained Colton Association. The shear and compressive strengths of Colton soils are good and the susceptibility to shrinkage and swelling is low. It is also a very good source of road building material, as evidenced by the excavations. The water table should be deep and the rapid permeability should not inhibit the function of septic tanks. Topsoils derived from Colton soils are usually quite poor.

The poor agricultural response coupled with the excellent engineering properties of Colton soils, makes them ideal for industrial development.

SIZE: Approximately 2.2×10^6 sq. ft. (0.21 sq. km.).

This is dependent upon the status of the excavation.

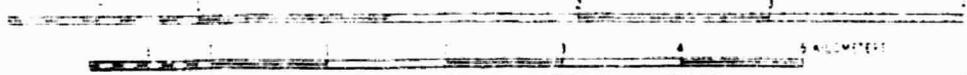
Figure 4



U.S. GEOLOGICAL SURVEY
 WATER RESOURCES DIVISION
 VERMONT
 JULY 17 1961
 1:25,000
 62721



**ORIGINAL PAGE IS
OF POOR QUALITY**



WATER: The Colton soil may act as an aquifer, although the ground water may have been disrupted by the excavation. No surface water sources are immediately adjacent to the site.

ACCESSIBILITY: Very good via Alstead Mill and Limekiln Roads. It is just one mile from the Village of Keene and NYS Routes 73 and 9N.

SITE PREPARATION REQUIRED: Development would have to wait until the extraction operation is finished, and would be a matter of reclaiming the land.

ADVANTAGES: It is very accessible. The soil--or what is left of it--has excellent engineering characteristics. It is hidden from view. It would displace no agriculture.

DISADVANTAGES: The current land use. Water availability may be a problem.

LP2

LOCATION: Two miles (3.2 km.) southwest of Upper Jay on Bartlett Road.

(Figure 4.)

EXISTING LAND USE/

GROUND COVER: The tract is thinly wooded. It appears to have been cleared for lumber or agriculture in the recent past and is in the early stages of succession. Adjacent areas are more densely wooded.

SOIL: The proposed site is on a till covered upland. The General Soils Maps defines the soil as of the Hermon Association, a bouldery, sandy loam, derived from glacial till. The soil is generally deep (greater than 5 ft. (1.5 m.) to bedrock), well-to-excessively drained with a water table depth usually in excess of 4 ft. (1.2 m.). The shear and compressive strengths of Hermon soils are good, and they are capable of bearing structures. Shrinking and swelling are low, and the elevated topographic position makes them unlikely to be flood prone. Septic tanks should operate satisfactorily in these soils. Hermon soils are poor aquifers because of their compacted till origins. They are poor agricultural soils because of their strong acidity, excessive drainage, and stoniness.

In sum, Hermon soils are excellent for building upon and will not suffer from lost agricultural potential.

SIZE: Approximately 2.0×10^6 sq. ft. (0.19 sq. km.) have been cleared.

There is potential for doubling or tripling this and remaining in the good soil area.

WATER: Because it is located on a terrace, it may collect any ground water moving along the soil/crystalline rock contact. Surface water is not visible nearby.

ACCESSIBILITY: Bartlett Road runs through the site. It is two miles (3.2 km.) away from the Village of Upper Jay and NYS Route 9N.

SITE PREPARATION REQUIRED: Little, the tract is gently sloping. The tree cover has fairly recently been cleared and is still thin. No access roadways would be required.

ADVANTAGES: The soil has good engineering properties. The site is not densely wooded and there is no agriculture on or adjacent to it. It is easily accessible by road.

DISADVANTAGES: Tall buildings or smokestacks may be visible from Route 9N across the valley. Water availability may be limited.

ORIGINAL PAGE IS
OF POOR QUALITY

LP3

LOCATION: 1 1/2 miles (2.4 km.) northwest of Keene along Bartlett and Lacy Roads. (Figure 4.)

EXISTING LAND USE/

GROUND COVER: This tract of land at the footslopes of Sentinal Mountain is primarily wooded. There is a single farm just south of the site. The remainder of the neighboring land is wooded.

SOIL: The airphoto tones indicate dry ground conditions. According to the General Soils Map the soils should be of the Windsor Association, deep, excessively-drained soils with coarse texture. The water table is usually at a depth greater than 4 ft. (1.2 m.) and the depth to bedrock is also generally greater than 4 ft. (1.2 m.). Although shear and bearing strengths are fairly low, the soils are capable of supporting buildings with or without basements, provided the slopes are less than 8%, which is the case here. The rapid permeability makes Windsor soils suitable for septic tanks. They do not shrink or swell to any large extent and are not susceptible to frost action. The sandy texture makes them fairly poor agricultural soils.

SIZE: It is very large, approximately 20.0×10^6 sq. ft. (1.86 sq. km.).

WATER: A small amount of ground water may be available under the till soil.

Surface water is in the form of two streams that cross the site.

ACCESSIBILITY: It is only one mile (1.6 km.) from NYS Route 9N and may be approached via several roads.

SITE PREPARATION REQUIRED: Trees must be cleared. Some grading might be required. Construction material (sand and gravel) is available nearby at site LP1.

ADVANTAGES: It is a very large, gently sloping, largely undeveloped tract. It is very close to a major travel corridor, yet should be hidden from view. Development is not likely to be disruptive to adjacent land uses.

DISADVANTAGES: The tree cover requires clearing. Ground water may not be readily available.

LP4

LOCATION: Midway between Wilmington and Upper Jay on Hardy-Kilburn Road.
(Figure 4.)

EXISTING LAND USE/

GROUND COVER: The tract is thinly wooded. It appears that it might have been cultivated at one time and then abandoned. Farming continues nearby, about one mile away.

SOIL: The proposed site is on a till covered hillside. The soils appear well-drained and are probably of the Hermon Association as is the case for site LP2. The Soil Map described it as a bouldery, sandy loam, derived from glacial till. The soil is generally deep (greater than 5 ft. (1.5 m.) to bedrock), well-to-excessively drained with a water table depth usually in excess of 4 ft. (1.2 m.). The shear and compressive strengths of Hermon soils are good, and are capable of bearing structures. Shrinking and swelling are low, and the good permeability should aid the operation of septic tanks. Hermon soils are poor aquifers because of their compacted till origins. They are poor agricultural soils because of their strong acidity, excessive drainage, and stoniness.

SIZE: Approximately 1.4×10^5 sq. ft. (0.13 sq. km.). It is bounded on one side by a steep ridge and on the other by wet lowlands.

WATER: Beaver Brook runs by the lower edge of the site.

ACCESSIBILITY: It is one-half mile from the main road between Wilmington and Upper Jay. No access road is needed. It is fairly well hidden from the travel corridor.

SITE PREPARATION REQUIRED: Little is required because the tree cover has not yet fully returned. It is adjacent to the road and the slopes are gentle.

ADVANTAGES: The soil is good for construction. Agriculture has apparently already been abandoned on the site. It is easily accessible and requires little site preparation.

DISADVANTAGES: Industrial development may be disruptive to the remaining agriculture nearby.

LP5

LOCATION: One mile (1.6 km.) north of site LP4, on the Hardy-Kilburn Road.

It is also 2 miles south of NYS Route 86. (Figure 4.)

EXISTING LAND USE/

GROUND COVER: The tract of land straddles a lightly-travelled road.

It is made up of small parcels of woods and open fields that appear to have been farmed at one time and then abandoned. Farming continues about 1/4 mile away.

SOIL: The site is on a terrace and has the light photographic tones of a well-drained soil. It was likely formed in glacial outwash and is probably of the Windsor Association, deep, excessively-drained soils with coarse texture. The water table is usually at a depth greater than 4 ft. The water table may be closer than 4 ft. to the surface on the valley side of the site and the soil quite shallow on the upland site. Although shear and bearing strengths are fairly low, the soils are capable of supporting buildings with or without basements, provided the slopes are less than 8%, which holds true in this case. The rapid permeability makes Windsor soils suitable for septic tanks. They do not shrink or swell to any large extent and are not susceptible to frost action. The sandy texture makes them fairly poor agricultural soils.

SIZE: There is approximately 1.4×10^6 sq. ft. (0.13 sq. km.) that appears currently available for development. If the nearby farms follow the lead of the others in the valley, presumably room for expansion will become available.

WATER: The soil may bear the water that moves downhill along the contact between the permeable soil cover and the crystalline bedrock. Beaver Brook is nearby.

ACCESSIBILITY: Hardy-Kilburn Rd. passes by the site. No driveway would be required.

SITE PREPARATION REQUIRED: Some trees would need clearing. The land is level-to-sloping and would require some grading.

ADVANTAGES: It has good soil for construction and should be well drained over most of the site. It is easily accessible and requires little site preparation. There is apparently no farming ongoing on the site.

DISADVANTAGES: Industrial development might disrupt the few remaining farms in the valley. The water table may be high on the valley side.

LP6

LOCATION: Across the valley from LP5, on Perkins Rd. (Figure 4.)

EXISTING LAND USE/

GROUND COVER: The tract is wooded. Perhaps it had been farmed at one time. It is at the base of Bassett Mountain, hidden from the valley on the other side of a hill. Paleface Ski Resort is 1 1/2 miles (2.4 km.) distant, part-way around Bassett Mtn. The immediately adjacent lands are wooded.

SOILS: Both Hermon and Winsor Associations are found on the site.

HERMON ASSOCIATION - A bouldery, sandy loam, derived from glacial till. The soil is generally deep (greater than 1.5m. to bedrock), well-to-excessively drained with a water table depth usually in excess of 1.2m. The shear and compressive strengths of Hermon soils are good, and are capable of bearing structures. Shrinkage and swelling are low, and the site's elevated topographic position makes it unlikely to be flood prone. Septic tanks will operate satisfactorily in these soils. Hermon soils are poor aquifers because of their compacted till origins. They are poor agricultural soils because of their strong acidity, excessive drainage, and stoniness.

In sum, Hermon soils are excellent for building upon and will not suffer from lost agricultural potential.

WINDSOR ASSOCIATION - Deep, excessively-drained soils with coarse texture. The water table is usually at a depth greater than 1.2m. and the bedrock depth is also generally greater than 1.2m. Although shear and bearing strengths are fairly low, the soils are capable of supporting buildings with or without basements, provided the slopes are less than 8%. The rapid permeability makes Windsor soils suitable for septic tanks. They do not shrink or swell to any large extent. The sandy texture makes them fairly poor agricultural soils.

SITE: The thinly wooded area on the saddle of the hill is approximately 1.6×10^6 sq ft. (0.15 sq. km.). This could be expanded four-fold to the south by the removal of more trees. To the north expansion is only limited by visibility from NYS Route 86.

WATER: There may be some ground water moving downhill at the soil/rock contact.

ACCESSIBILITY: The site may be reached from the Wilmington area via Perkins Road and from the Jay and Upper Jay areas via Stone House Road.

SITE PREPARATION REQUIRED: Trees must be felled. Some grading may be required of the slopes which range from 0-10% on the site.

ADVANTAGES: It is not used for agriculture. The soil is fit for construction and should have no drainage problems. A road passes near the site. It is hidden from towns and travel corridors.

DISADVANTAGES: Some trees must be cleared. Water may not be readily available.

LOCATION: Just inside the border with Franklin County, on Roslyn Lane, about 1 1/2 miles (4 km.) from the Village of Franklin Falls. It is about 8 miles (13 km.) northwest of Wilmington. (Figure 5.)

EXISTING LAND USE/

GROUND COVER: The tract is wooded as is most of the surrounding land. There are some residences and a school within a mile of the site, which is at the base of Hatton Hill.

SOIL: The site is on terrace, probably formed in outwash and likely of the Colton Association, deep, excessively-drained sandy to gravelly soils, developed in glacial outwash. Shear and compressive strengths are good and shrinking and swelling are low. It is excellent for building upon. It is also a very good source of road-building material. The water table is usually greater than 1.0 m. and bedrock is at least as great. The rapid permeability of the soil makes it excellent for septic tanks. Ground water is often plentiful. Topsoils derived from Colton soils are usually quite poor.

The poor agricultural response coupled with the excellent engineering properties of Colton soils, makes them ideal for industrial development.

SIZE: Approximately 1.1×10^6 sq. ft. (0.19 sq. km.)

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 5



ORIGINAL PAGE IS
OF POOR QUALITY

WATER: The coarse Colton soils often bear water. The site's location at the base of Hatton Hill might yield some water that has moved downhill. There is a small pond just southeast of the site.

ACCESSIBILITY: It is on Rosylyn Lane, fairly close to the Franklin County town of Franklin Falls. It is quite removed from the nearest village in Essex Co. (Wilmington, 8 miles away).

SITE PREPARATION REQUIRED: Trees must be felled. No access road is needed.

ADVANTAGES: The Colton soils are excellent for building and unlikely to support agriculture. It is the only possible site in this large, remote area of the county.

DISADVANTAGES: It is distant from the developed areas of Essex County.

AU SABLE FORKS QUAD

With the exception of the southwest corner of the quadrangle, most of the land is privately-owned, and so has the potential for development. A mountainous region cuts across from southwest to northeast, limiting development for all practical purposes, to the northwest and southeastern quadrants.

The land to the northwest is occupied by a large campgrounds, spread over approximately ten square miles (26 sq. km.). The few intermontane valleys in the center of the quadrangle are filled with ponds and wet ground.

Most of the level land between Jay and North Jay is used for agriculture. Some tracts of land within this agricultural region are no longer used for farmland and may be suitable for industrial development. One such site discussed below, is A-1. Three other hillside sites in this region merit consideration.

The other promising location for industrial siting is a valley in the eastern portion of the quadrangle, north of Lewis, near the Northway and U.S. 9.

ORIGINAL PAGE IS
OF POOR QUALITY

Aul

LOCATION: Between Jay and Upper Jay on Plains (Valley) Road, about two miles (3.2 km.) northeast of Upper Jay and 2 mi. (3.2 km.) south of Jay. (Figure 6.)

EXISTING LAND USE/

GROUND COVER: There is an operating farm just south of the proposed site and a few abandoned farms to the north. The site itself is no longer being farmed, but there appears to be a broad, shallow extraction operation going on.

SOIL: The soils appear deep and dry. The soils map designates the area as having Windsor Association soils, which have good engineering characteristics and make poor agricultural soils.

SIZE: It is approximately 2.0×10^6 (1.9×10^5 sq. m.) sq. ft., with expansion limited by agricultural uses of neighboring lands.

WATER: The soil may be water bearing. There is no surface water readily available.

ACCESSIBILITY: Very good. It is close to Route 2N. No access road need be constructed.

Figure 6



ORIGINAL PAGE IS
OF POOR QUALITY

SITE PREPARATION REQUIRED: Very little. Some trees may need to be felled if it is desired to leave the farm land intact. A road passes along the site.

ADVANTAGES: Ease of access. Good soil for construction. Little site preparation required. Level ground. It is close to, but not visible from, travel corridors.

DISADVANTAGES: Industrial use might disrupt the neighboring agriculture, but probably no more so than the existing extraction operation. Industrial use depends on the status of the extraction operation. The site might be visible from 9N.

Au2

LOCATION: Along Styles Brook Road, at the base of Clements Mountain.
(Figure 6.)

EXISTING LAND USE/

GROUND COVER: The tract is wooded as is most of the surrounding area.
A few isolated farms are nearby.

SOILS: Its terrace location and well-drained appearance indicate a deep, coarse-textured outwash soil. Windsor Association is the classification given it by the General Soils Map. Windsor soils are capable of supporting buildings. The elevated position should free the site from drainage problems and the droughtiness of the soil should rule out its agricultural use.

SIZE: It is approximately 2.2×10^6 sq. ft. (2.1×10^5 sq.m.).

WATER: The soil should bear ground water. No surface water is visible.

ACCESSIBILITY: The site is adjacent to Styles Brook Rd.

SITE PREPARATION REQUIRED: The tree cover would need to be cleared.

Some grading might be necessary.

ADVANTAGES: The soil should be good. It is hidden from view. Ground water should be available.

DISADVANTAGES: Trees would need clearing. The local agriculture might suffer.

Au3

LOCATION: 1.5 miles (2.4 km.) east of the Village of Jay, between Bull Hill and the base of Lincoln Mtn. (Figure 6.)

EXISTING LAND USE/

GROUND COVER: The tract is partially cleared, apparently having been farmed at one time. The farm house is still visible. Just north of the site is a small farm. The remainder of the nearby land is densely wooded.

SOIL: The proposed site is on an elevated tract between a steep mountainside and a small till-covered, bedrock knob. The soil of the site appears well-drained and is reportedly of the Windsor Association, believed to be formed in outwash. As such, it should be suited for construction and fairly poor for agriculture. Its topographic position and coarse-texture should free it from drainage problems.

SIZE: It is approximately 2.1×10^6 sq.ft. (2.1×10^5 sq.m.).

WATER: Ground water is likely to collect in the coarse soils that fill this hillside bedrock trough. Surface water is not visible.

ACCESSIBILITY: A road leads directly to the site.

SITE PREPARATION REQUIRED: Little is needed, as the land was farmed not
long ago.

ADVANTAGES: It should have good soil; it is already cleared; it is hidden
from view behind Bull Hill.

DISADVANTAGES: The local farms may be adversely affected.

Au4

LOCATION: 1.5 miles (2.4 km.) northeast of the Village of North Jay.
(Figure 7.)

EXISTING LAND USE/

GROUND COVER: The proposed site is part of a large, thinly wooded area that appears to be part of an abandoned farm that has apparently consolidated its operations to the more fertile adjacent land.

SOIL: It is on a small terrace that flanks the southern base of Haystack Mtn. Through the thin tree cover the soil appears dry. Similar in land form and appearance to that of sites Au2 and 3, it is likely to have similarly good soils for construction.

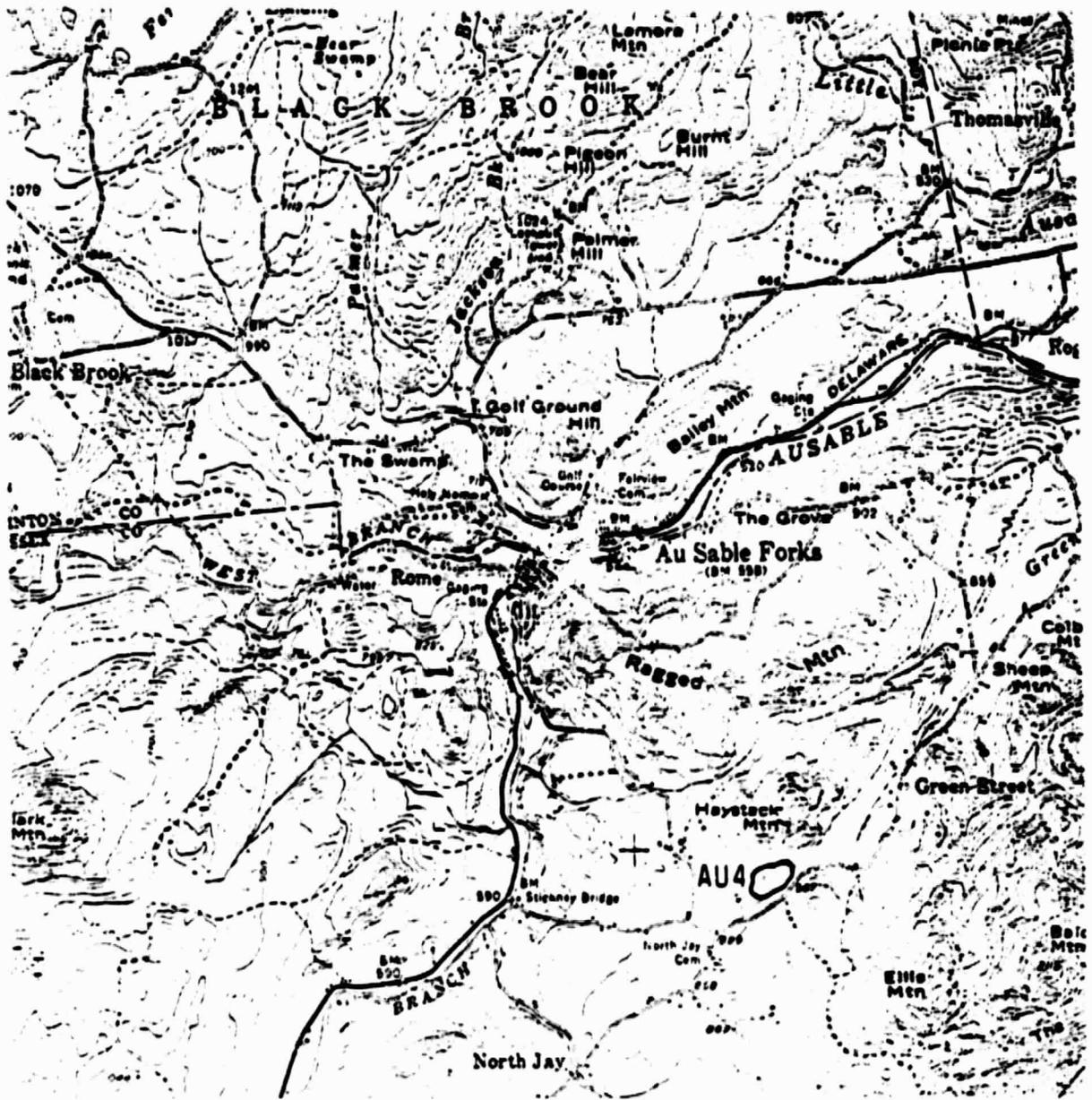
SIZE: It is approximately 1.2×10^6 sq. ft. (1.1×10^5 sq.m.), bounded by woodland that could be cleared to expand the site.

WATER: Ground water may be available. No surface water is visible.

ACCESSIBILITY: A road passes by the site.

SITE PREPARATION REQUIRED: It requires little, having been cleared for farming.

Figure 7



ORIGINAL PAGE IS
OF POOR QUALITY

ADVANTAGES: The soil appears good. It is only thinly wooded.

DISADVANTAGES: Nearby agriculture might be affected by an industrial use.

Au5

LOCATION: On Pond Road, one mile (1.6 km.) northwest of U.S. 9, five miles (8 km.) north of Lewis. (Figure 8.)

EXISTING LAND USE/

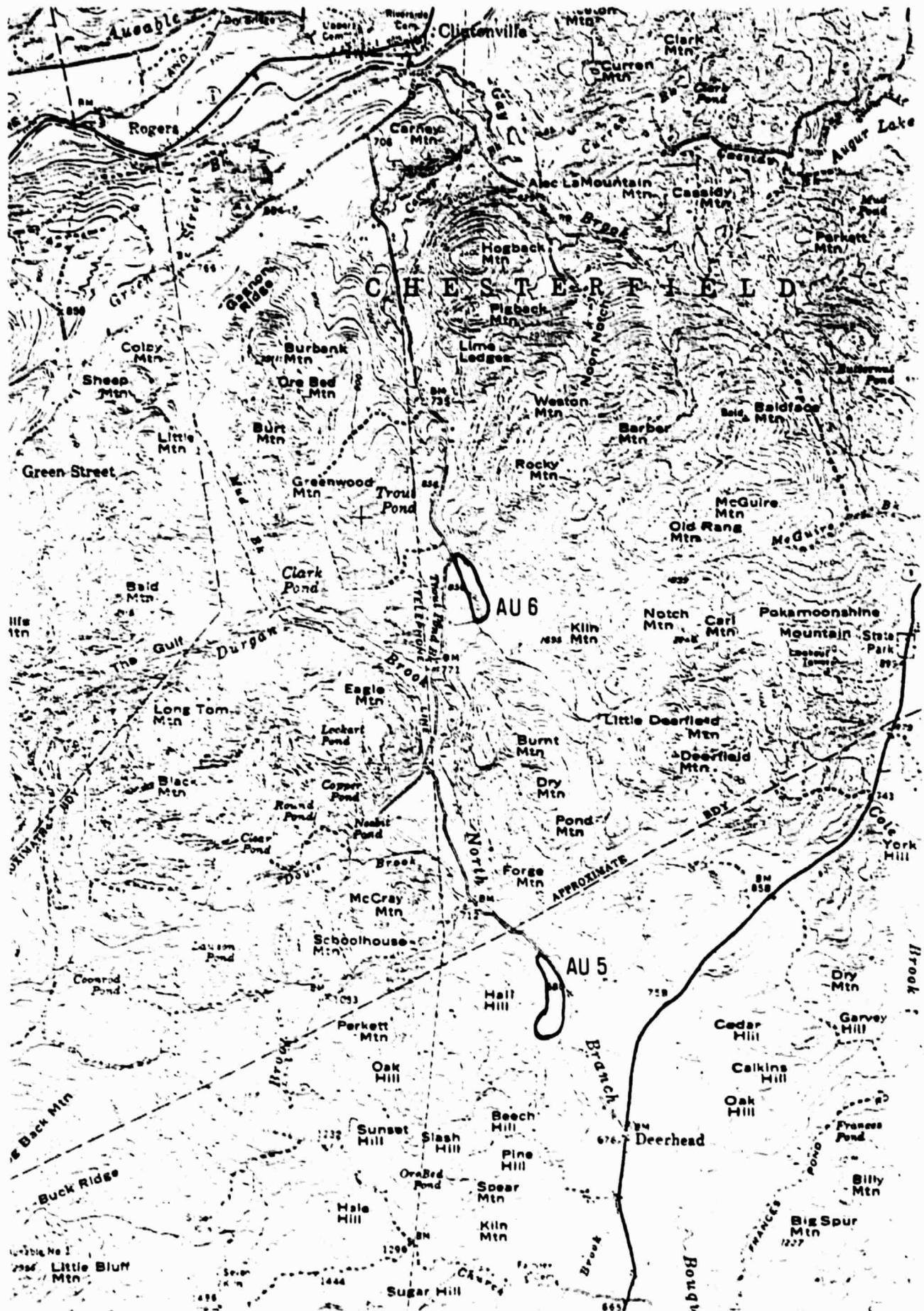
GROUND COVER: The land is partially cleared, surrounded by dense forests. It appears to have been a farm at one time. Currently there are two very small excavations (sand and gravel, most likely) visible on the site and a farmhouse near the road.

SOIL: The site is on a terrace above a narrow valley. It appears well-drained, and the presence of the two pits would seem to indicate a coarse-grained soil. The soil map designation is Colton Association, an outwash-derived soil. It should be deep and very well-drained on this terrace location, and should provide excellent support for buildings.

SIZE: It is approximately 2.4×10^6 sq.ft. (2.3×10^5 sq. m.), with a potential for expansion along Pond Road.

WATER: There is a small stream in the valley. Ground water should collect in the terrace.

Figure 8



ORIGINAL PAGE IS
OF POOR QUALITY

Au5

SITE PREPARATION REQUIRED: The pits would require grading to restore the site for industrial use. The trees are already cleared.

ADVANTAGES: Its location is excellent, as are the soils. Water should pose no problem.

DISADVANTAGES: Part of the site is currently in use as a gravel pit.

Au6

This proposed site is very close to site Au5 and is on a similar terrace, probably formed in the same outwash. The only observable difference between the two sites are the land use. Au6 is wooded.

WILLSBORO QUADRANGLE

The Lake Champlain lowlands constitute the eastern half of the Willsboro quadrangle. Most of this land, except for the wetlands, is farmed. The western region has a large area of rugged terrain. Virtually all of the land is privately owned.

There are no visible, potential sites in the upland area, as all of the intermontane basins appear wet. The most desirable soils for development appear to cover large areas in and around the Village of Willsboro. As such, development recommendations in this region will be left to the governing bodies.

SANTANONI QUADRANGLE

More than half of the land in the Santanoni quadrangle is state-owned and virtually all is rugged. The relatively level, privately owned land near Wolf Pond in the southwest corner of the quadrangle is too poorly drained to be developed. Two sites do merit consideration in this area.

SA1

LOCATION: At the northwest end of Beaver Flow, one mile east of Newcomb (1.6km.) Lake, and three miles north of NYS Route 28N at Winebrook. (Figure 9.)

EXISTING LAND USE/

GROUND COVER: The tract is wooded, although not quite as densely as the surrounding forest land. Perhaps it was cleared for lumber at one time.

SOIL: COLTON ASSOCIATION - Deep, excessively-drained sandy to gravelly soils, developed in glacial outwash. Shear and compressive strengths are good and shrinking and swelling are low. It is excellent for building upon. It is also a very good source of road-building material. The water table depth is usually greater than 4 ft. and bedrock depth is at least as great. In this case the water table may be high along the northern edge of the site. Topsoils derived from Colton soils are usually quite poor.

The poor agricultural response coupled with the excellent engineering properties of Colton soils, makes them generally ideal for industrial development.

SIZE: Approximately 2.3×10^6 sq. ft. (0.22 sq. km.), bounded by steep land on one side and wetlands on the other.

Figure 9



NEADOMBY 6771 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000
 SA 1 SA 2
 SCALE 1:62500
 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
 METERS

ORIGINAL PAGE IS
 OF POOR QUALITY

WATER: It is adjacent to Beaver Flow, a large body of water. Ground water should be available in the soil, although the bedrock is crystalline and will not bear water.

ACCESSIBILITY: It is 3 miles from NYS Route 28N. A dirt or gravel road (apparently an old lumber road) already passes through the site.

SITE PREPARATION REQUIRED: Moderately dense tree cover would have to be removed. The slopes are moderate and might require grading.

ADVANTAGES: The soil properties are excellent for construction. It is a tract of privately owned land in an area that is otherwise predominantly state-owned. It is hidden from view and does not require the clearing of dense forest, as would be required in much of the surrounding land. The sandy and gravelly nature of the soil would limit any conceivable agricultural usage.

DISADVANTAGES: It is fairly far from the nearest highway (3 miles). Development might be disruptive to other uses of Beaver Flow. Some forest growth must be cleared.

SA2

LOCATION: Near Tahawus, 4.2 miles from NYS Route 28N, along the eastern side of the Delaware and Hudson Railroad tracks.(Figure 9.)

EXISTIN LAND USE/

GROUND COVER: Wooded. The adjacent land uses are industrial, related to the large mining operation at Tahawus.

SOIL: COLTON ASSOCIATION - Deep, excessively-drained sandy to gravelly soils, developed in glacial outwash. Shear and compressive strengths are good and shrinking and swelling are low. It is excellent for building upon. It is also a very good source of road-building material. The rapid permeability of the soil make it excellent for septic tanks. Ground water is often plentiful. Topsoils derived from Colton soils are usually quite poor. The water table appears to be high in parts of the site. Much of the surrounding land is wet. This might restrict building. The site is just above the flood plain of the Opalescent River and might be flood prone.

SIZE: Depending upon the amount of dry ground, it may be as large as 12.8×10^6 sq. ft. (1.19 sq. km.).

WATER: The Opalescent River passes by the site. Ground water may be found in the coarse-textured soils over the crystalline basement rocks.

ACCESSIBILITY: Very good. It is close to the Taha-us-Sanford Road. The Delaware and Hudson Railroad passes through the site.

SITE PREPARATION REQUIRED: Trees must be cleared. The slopes are relatively low.

ADVANTAGES: The site is potentially very large depending upon the limits of the wet ground. It is accessible by highway and railroad. The surrounding land uses are industrial and would not be adversely affected. The approach road is not likely to be used by tourists. (Crushed stone is available at the neighboring mine.)

DISADVANTAGES: It is distant from any villages. Trees need clearing and it may be poorly drained in whole or in part.

MOUNT MARCY QUADRANGLE

The Mount Marcy quadrangle contains the High Peaks region of the Adirondacks. Not surprisingly, most of the land is too steep to build upon (overlay 2). Most of the land is also state-owned (overlay 1).

The soils and slopes in Keene Valley are suitable for development. The narrowness of the valley, however, limits the degree to which buildings could be hidden to preserve the "character of the hamlet" as dictated by the APA guidelines. In addition, much of the level land is used for agricultural purposes.

There are a few extraction pits adjacent to NYS Route 73 that might be suitable for reclamation for industrial purposes.

The following sites have some potential for development, should any be desired in this remote section of the county.

ORIGINAL PAGE IS
OF POOR QUALITY

MM1 and MM1A

LOCATION: Between Elk Lake and Clear Pond, 3 miles (4.8 km.) north of Boreas Road near Blue Ridge, along Elk Lake Road. There are two neighboring sites, across the valley from one another. (Figure 10.)

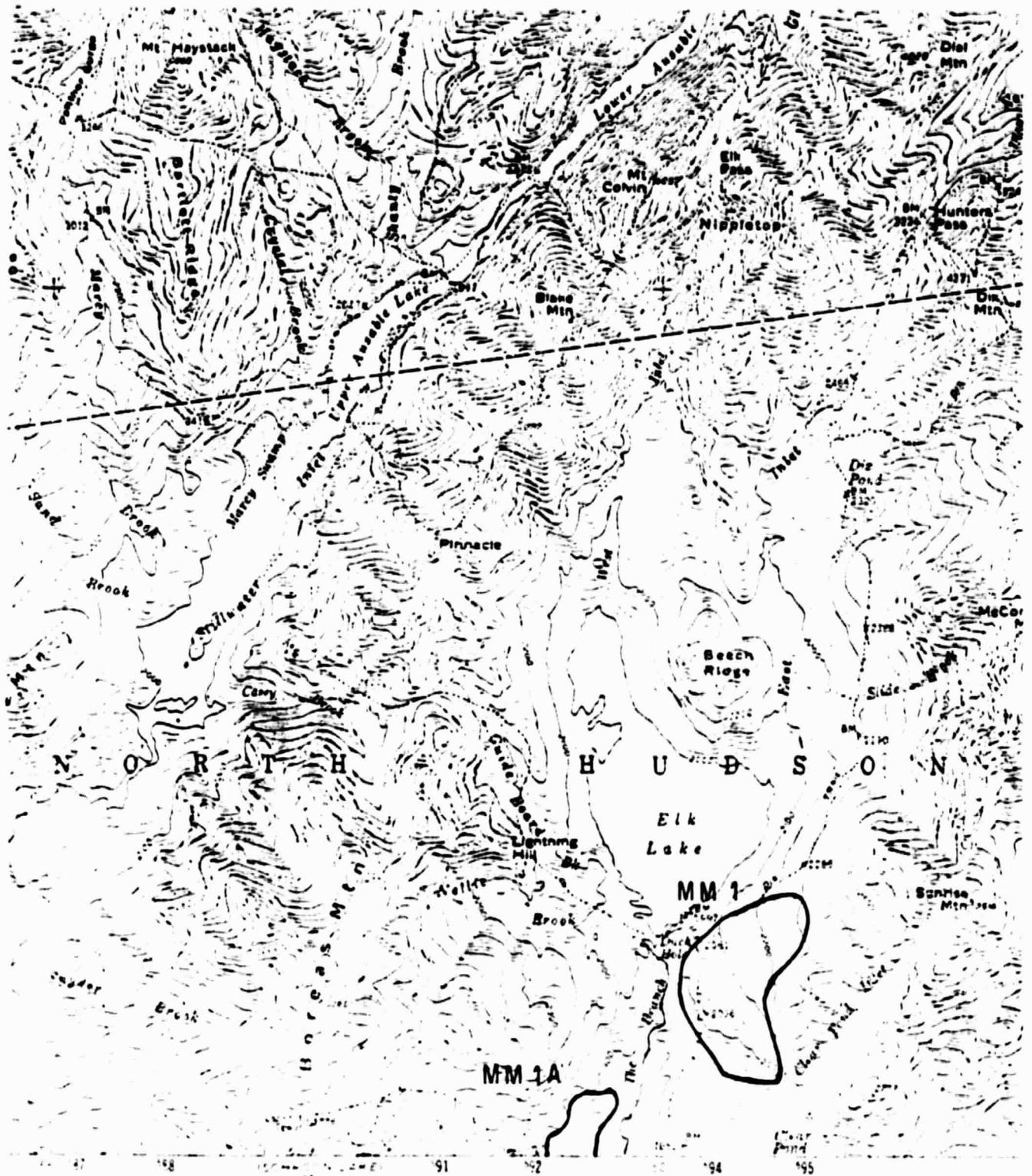
EXISTING LAND USE/

GROUND COVER: Both tracts are wooded, as is the surrounding land. There are a few campsites at the southern end of Elk Lake.

SOIL: They are hillside sites, appear dry, and are reportedly covered with soil of the Hermon Association, a bouldery, sandy loam, derived from glacial till. The soil is generally deep (greater than 5 ft. to bedrock), well-to-excessively drained with a water table depth usually in excess of 4 ft. The shear and compressive strengths of Hermon soils are good, and they are capable of bearing structures. Shrinking and swelling are low, and the elevated topographic positions of the sites make them unlikely to be flood prone. Septic tanks should operate satisfactorily in these soils. Hermon soils are poor aquifers because of their compacted till origins. They are poor agricultural soils because of their strong acidity, excessive drainage, and stoniness.

In sum, Hermon soils are excellent for building upon and will not suffer from lost agricultural potential.

Figure 10



ORIGINAL PAGE IS
OF POOR QUALITY

SIZE: MM1: 18.3×10^6 sq. ft. (17.0×10^5 sq. m.).
MMLA: 3.6×10^6 sq. ft. (3.4×10^5 sq. m.).

WATER: There is plentiful surface water, with Elk Lake and Clear Pond nearby. The Branch River runs in the valley between the two sites. Groundwater may be limited due to the dense till over bedrock ground conditions.

ACCESSIBILITY: Elk Lake Road leads directly to the sites. The site area is roughly six miles (9.6 km.) from Northway Exit 29 (North Hudson).

SITE PREPARATION REQUIRED: Trees must be cleared. The slopes are somewhat less than 5%, so a small amount of grading may be required.

ADVANTAGES: The sites are very large and relatively flat. The soil is not suitable for agriculture, but is very good for building construction. Accessibility by road is very good. The land is hidden from view.

DISADVANTAGES: It is a few miles from the nearest town. Dense tree cover must be cleared. Any local recreational activities might be affected.

MM2

LOCATION: Along Indian Pass Brook, 3 miles (4.8 km) south of the Hamlet of North Elba, west of Heart Lake Road. (Figure 11.)

EXISTING LAND USE/

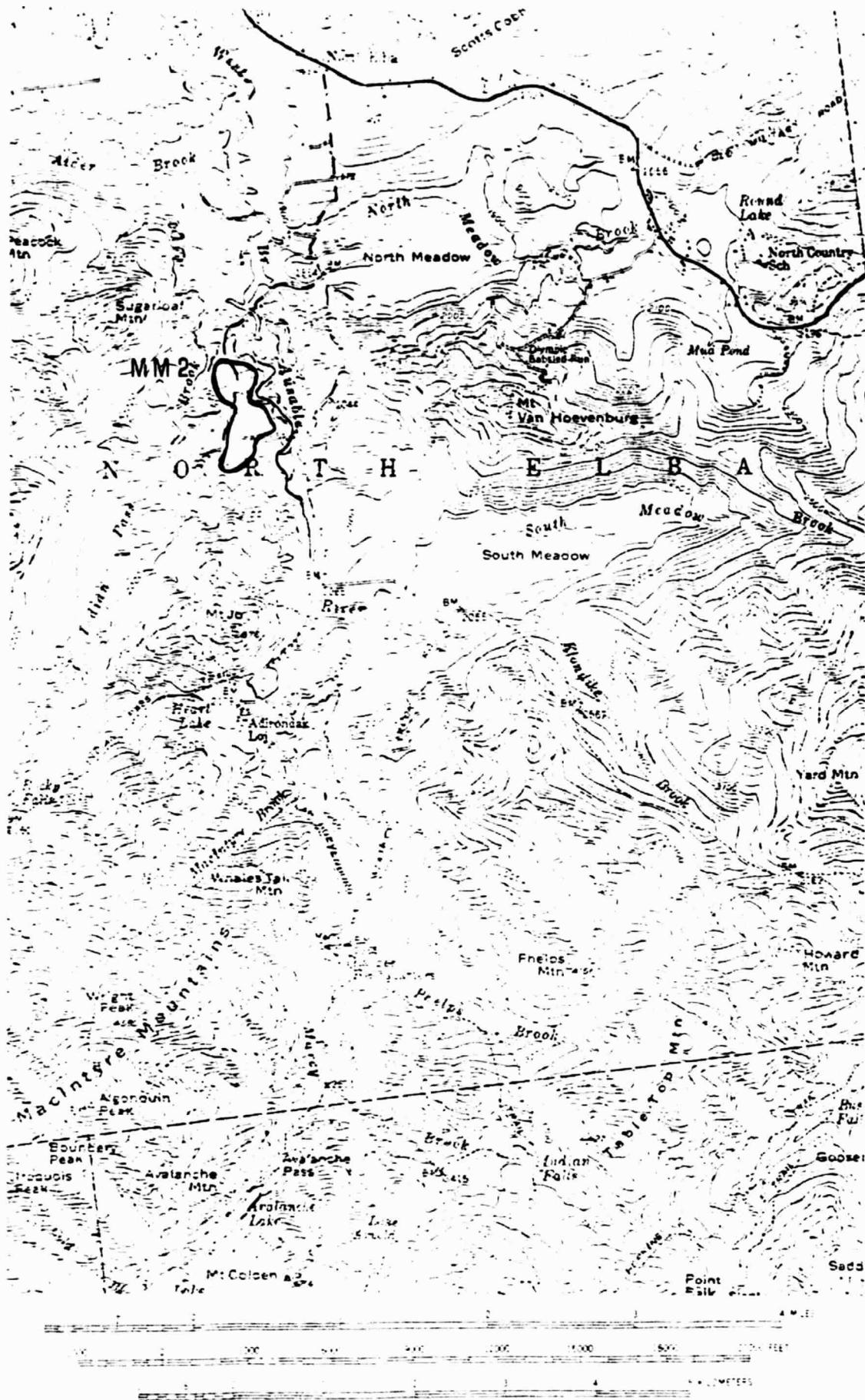
GROUND COVER: The site is partially wooded and partially cleared for agricultural purposes, which may have been abandoned.

SOIL: COLTON ASSOCIATION - Deep, excessively drained sandy to gravelly soils, developed in glacial outwash. Shear and compressive strengths are good and shrinking and swelling are low. It is excellent for building upon. It is also a very good source of road-building material. The water table depth is usually greater than 4 ft. (1.2 m.) and bedrock depth is at least as great. The rapid permeability of the soil make it excellent for septic tanks. Ground water is often plentiful. Topsoils derived from Colton soils are usually quite poor.

The poor agricultural response coupled with the excellent engineering properties of Colton soils makes them ideal for industrial development.

SIZE: It is approximately 4.1×10^6 sq. ft. (3.9×10^5 sq. m.).

Figure 11



ORIGINAL PAGE IS
OF POOR QUALITY

WATER: The Colton soil may be a good aquifer. Indian Pass Brook may be a surface source of water.

ACCESSIBILITY: It is 3 miles from NYS Route 73 on a side road off Heart Lake Road. No additional roadways need be constructed to the site.

SITE PREPARATION REQUIRED: Little is required; much of the site has already been cleared of trees.

ADVANTAGES: The soil has excellent engineering characteristics and may have only marginal value for agriculture. The site is relatively level. It is hidden from view.

DISADVANTAGES: If the current agricultural activity is productive, it would be a loss to build here.

ELIZABETHTOWN QUADRANGLE

There are only six sections of the Elizabethtown quadrangle that are not either State-owned, too steep to build upon or both: the corridor along U.S. 9 between New Russia and Elizabethtown, the Moriah-Mineville valley, a tract of land on the northwestern end of Lincoln Pond, the Black River Valley in the northeast, land just north of Elizabethtown, and an area about three miles (4.9 km.) west of Elizabethtown.

The Northway occupies the Lincoln Pond and Black River valleys. The soils in the valley containing U.S. 9 are level and appear to have excellent engineering potential. However, the valley is very narrow, and buildings here would be conspicuous in this designated travel corridor. West of Elizabethtown there is a large, apparently abandoned farm straddling Route 9N. Its soils appear to be suitable for construction but it is highly visible from the highway. Nearby, along Hurricane Road, the land is also reasonably level, privately-owned, and apparently capable of supporting industrial development. The area is residential, though.

The Moriah-Mineville valley shows the most promise for industrial location.

LOCATION: Approximately two miles (3.2 km.) northwest of Moriah Center,
off of Chipmunk Road. (Figure 12.)

EXISTING LAND USE/

GROUND COVER: The tract appears to have been a recently abandoned farm.
The surrounding lands are wooded, with the nearest farm
approximately one quarter mile (0.4 km.) away.

SOIL: The proposed site is on a terrace on the side of Armstrong Mtn.,
rising approximately 100 ft. (30 m.) above the valley.
The Soil Map lists it as having Colton outwash soils,
which is consistent with its terrace position and light
airphoto tones. Colton soils have good engineering properties,
are well-drained, and generally make poor farmland, which may
explain the abandoned field. The depth to bedrock appears
great, and the water table should be low.

SIZE: The presently cleared field is approximately 2×10^6 sq. ft. (1.9×10^5 sq. m.). The site can be extended uphill by the removal
of trees.

WATER: Colton soils are generally good aquifers. With the exception of
a small stream to the north, there is no visible surface
water nearby.

ACCESSIBILITY: The site is easily accessible via Chipmunk Rd.

SITE PREPARATION REQUIRED: Very little. The land is level and already cleared.

ADVANTAGES: It is apparently unused by agriculture. It is already cleared. The soils should be excellent. It is very accessible, close to a travel corridor, yet hidden from view, and it is large.

DISADVANTAGES: Industrial development may interfere with the neighboring farm operation.

PORT HENRY QUADRANGLE

With the exception of the tip of Crown Point, none of the land in this quadrangle is State-owned. More than half of it is level enough to build upon. South of the Village of Westport is a large plain of fertile lakelaid clays. Farms cover all of the land that is not cut by streams. North of Westport is a continuation of the same fertile clay soil, intensively farmed except where steep bedrock hills intermittently rise, or where the streams cut through. Because of this, and because of its high visibility from highway and lake, the Lake Champlain lowland was eliminated from consideration as a site for industry. Furthermore, the soils are fairly uniform throughout and easily examined from the ground if siting is desired at some future time.

Two possible sites were located on the hillsides along the western edge of the quadrangle.

PH1

LOCATION: 3 1/2 miles (5.6 km.) south of Westport up the side of the hill from Stevenson Road. (Figure 13.)

EXISTING LAND USE/

GROUND COVER: Part of the tract is an open excavation and part is what appears to be an abandoned farm. The surrounding land is wooded. It is about half a kilometer from the valley farmland.

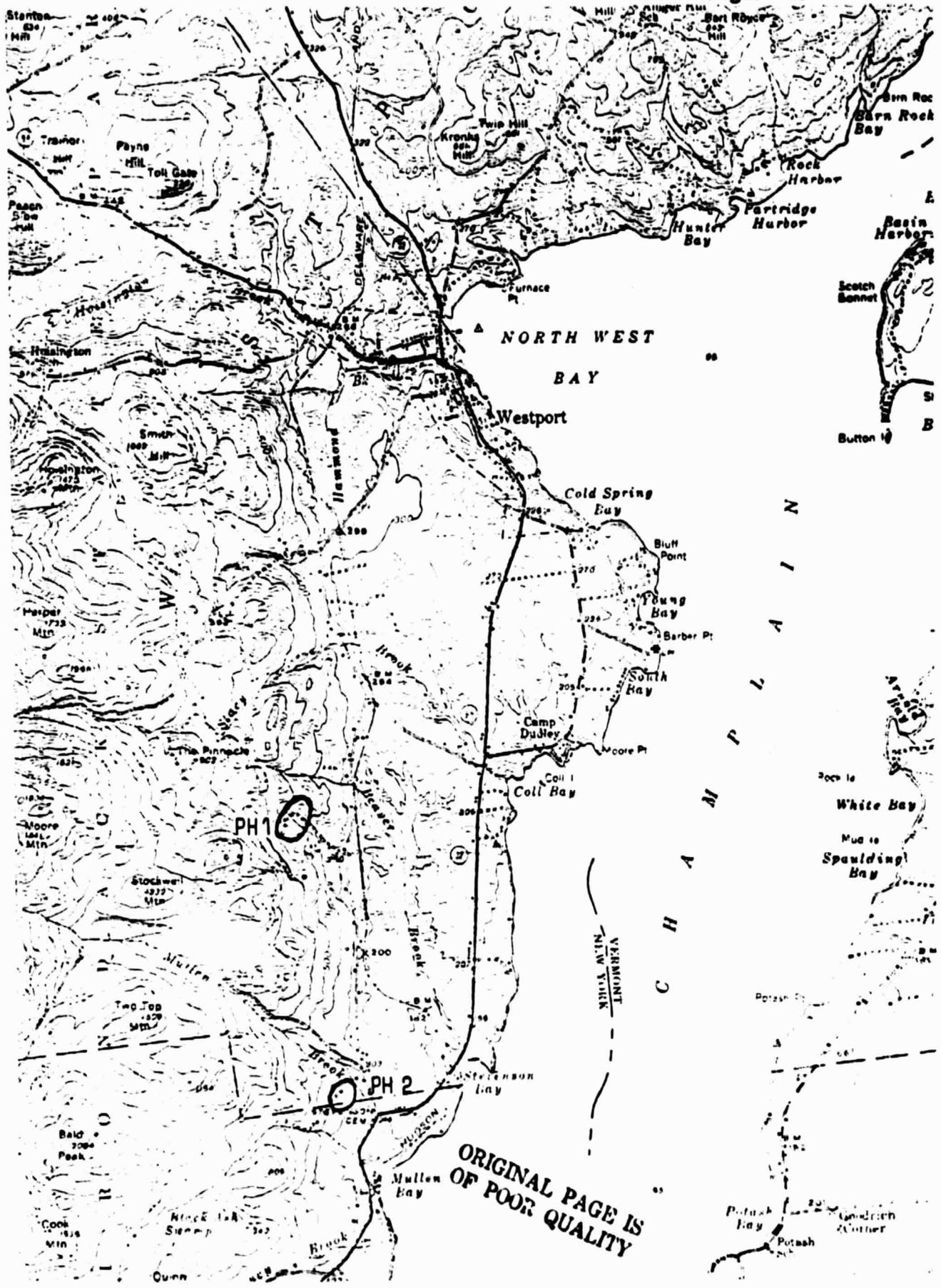
SOILS: The presence of a sand gravel pit and the terrace position would indicate a coarse textured, well-drained soil; one that perhaps formed on an ancient strand line or in glacial outwash. The Soils Map designation is the Colton Association, an excellent engineering soil. Its poor agricultural response may explain the abandoned farm.

SIZE: The site is approximately 2.2×10^6 sq. ft. (0.2 sq. km.), half of which is an open pit.

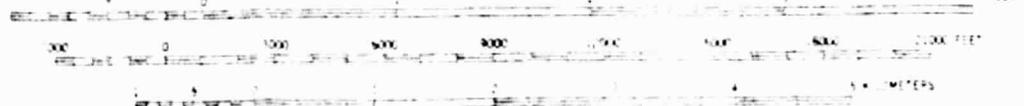
WATER: The coarse-grained soil may bear ground water. No surface water is visible. Lake Champlain is one mile (1.6 km.) away.

ACCESSIBILITY: A short road leads uphill to the site from the Lake Champlain Valley.

Figure 13



ORIGINAL PAGE IS OF POOR QUALITY



SITE PREPARATION REQUIRED: The northern half of the site would need little. The excavation would need grading to restore its suitability as an industrial site.

ADVANTAGES: The soils are probably excellent. It is close to a main highway, yet hidden from view. It does not displace any farms in this agricultural part of the county.

DISADVANTAGES: The sand/gravel operation might be a better use for the site.

ORIGINAL PAGE IS
OF POOR QUALITY

PH2

LOCATION: Near the junction of Routes 9N/22 and Stevenson Road, at the base of the hill. (Figure 13.)

EXISTING LAND USE/

GROUND COVER: Most of the trees have been cleared, probably in preparation for sand and gravel extraction. At the northern edge of the proposed site, two small pits are already in operation.

SOILS: The terrace position, the light tones, and the gravel pits all seem to indicate deep, coarse-textured, well drained soils, with desirable construction properties and a poor agricultural response. The General Soils Map lists the soil as of the Colton Association.

SIZE: Approximately 1.5×10^6 sq. ft. (1.4×10^5 sq. m.), with expansion along the terrace possible, but limited by visibility.

WATER: There is a good possibility that ground water is present. Lake Champlain is approximately 5/8 mile (1 km.) away.

ACCESSIBILITY: It is very close to a major highway, to the Delaware and Hudson Railroad, and to the Lake.

SITE PREPARATION REQUIRED: Grading.

ADVANTAGES: It is very accessible. The soil should be excellent. Much of the site is clear.

DISADVANTAGES: Siting an industry here would preempt its usage for sand and gravel extraction. Tall buildings may be visible from the travel corridor.

BLUE MOUNTAIN QUADRANGLE

Approximately 20 sq. mi. (52 sq. km.) of Essex County extends westward into the Blue Mountain Quadrangle. Three-quarters of this has slopes greater than 15%. There are a few unpaved paths that skirt the widespread wetlands of the lower ground. At a number of spots along the circuit of paths there are small clearings, presumably campsites. Recreation appears to monopolize the small amount of land in this part of the County and no suitable industrial sites were found.

NEWCOMB QUADRANGLE

The southeastern section of this quadrangle is almost entirely State-owned. There are three parcels of private land in this section, but they are apparently each used by clubs. The lowlands along the east bank of the Hudson River appear to be wet. A large tract of land--the remainder of the low land in the southern two-thirds of the quadrangle--is used for campsites or homes. Most of the lakes in this region appear to be intensively used for recreation.

A "scenic vista" was established at a point two miles east of the Village of Newcomb. The viewshed of this point encompasses much of the level land in the northeast section. Apparently, the only land in this quadrangle with potential for industrial development without displacing the current land uses is close to the Route 28N corridor in the western part of the County.

N1

LOCATION: On the south side of Baldwin Mtn., along Sucker Brook, about 1 1/2 miles (2.4 km.) northwest of the Village of Newcomb. (Figure 14.)

EXISTING LAND USE/

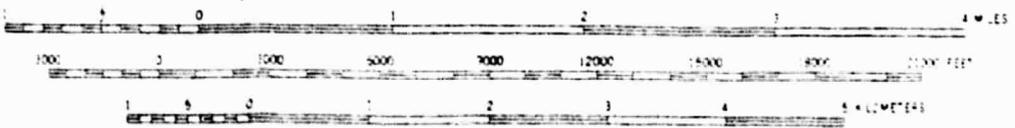
GROUND COVER: The proposed site is thinly covered with trees. It was recently cleared for lumber; the lumbering road still leads to the site. It is surrounded by forest.

SOIL: The soils appear dry on the airphotos. It has a hillside position, sufficiently elevated above the brook so that drainage should be no problem. Its soils are reportedly of the Becket-Peru Association, and may be fairly shallow to bedrock in some places. Becket-Peru soils are medium-to-coarse grained loams of till origin, and are capable of supporting buildings.

SIZE: The amount of reasonably level dry land on the site is approximately 1.0×10^6 sq. ft. (0.09 sq. km.). Three small streams flow past the site, defining its limits.

WATER: Three small streams pass the site. The till-derived soil may be poor in ground water.

Figure 14



ORIGINAL PAGE IS
OF POOR QUALITY

ACCESSIBILITY: It is over a mile (1.6 km.) from the highway, but directly accessible by an abandoned lumbering road.

SITE PREPARATION REQUIRED: Most of the tree cover was fairly recently cleared. Some grading is likely needed.

ADVANTAGES: It is close to NYS Route 28N and the Village of Newcomb, but is reasonably well hidden from view. Much of the tree cover was recently cleared.

DISADVANTAGES: It is on a hillside and would require some grading. It is a relatively small site.

LOCATION: One mile (1.6 km.) north of NYS Route 28N, near the eastern side of Arbutus Pond, about five miles (8.0 km.) northwest of the Village of Newcomb. (Figure 14.)

EXISTING LAND USE/

GROUND COVER: It was recently lumbered, and is surrounded by forest. It is about 1/4 mile (0.4 km.) from Arbutus Pond, which has one residential or recreational facility on its near shore.

SOIL: The tract is on the side of a small hill, with a wetland defining its lower limits. The site is sufficiently elevated to free it from water table problems. The soil map identifies the Becket-Peru Association at that location. These are medium-to-coarse grained soils of origin in glacial till. They have sufficient shear and compressive strengths to pose no problems to construction on the moderate slopes found on the site.

SIZE: The amount of land between the steep upland and the wet lowland is about 1.3×10^6 sq. ft. (0.12 sq. km.).

NZ

WATER: It is very close to a large pond. Ground water may also be available to a limited degree in the moderately coarse grained soil.

ACCESSIBILITY: It is accessible from east or west along small roads. The western approach appears to be a private drive, but the eastern approach, which is considerably longer, appears to be an abandoned lumbering road.

SITE PREPARATION REQUIRED: Little is needed to clear the remaining few trees from the site. Some grading may be necessary.

ADVANTAGES: It is close to the highway, but completely hidden. Trees are cleared and the soil is competent.

DISADVANTAGES: Construction might be disruptive to the current use of Arbutus Pond.

N3

LOCATION: On the Tahawas-Lake Sanford Road, four miles (6.4 km.) north of NYS Route 28N. It is a mile (1.6 km.) south and across the Hudson River Valley from site SA2. (Figure 15.)

EXISTING LAND USE/

GROUND COVER: It is tree covered, alongside a road leading to a large mine. All land within a few miles is wooded.

SOILS: It is on a terrace that rises above a wet, seemingly flood prone valley. The site appears well drained and is probably covered with the Colton Association's outwash soils. These are very permeable and should be well drained, which may be an important factor, since most of the lower lands around the site are wet. Colton soils have good shear and compressive strengths and a poor agricultural response.

SIZE: Depending upon the extent of the poorly-drained soils nearby, the site may be as large as 3.2×10^6 sq. ft. (0.31 sq. km.).

WATER: The Hudson River is 1000 ft. (0.3 km.) away. Ground water may also be plentiful.

Figure 15



ORIGINAL PAGE IS
OF POOR QUALITY

ACCESSIBILITY: It can be easily reached from the highway by a road which passes alongside of it. The Delaware and Hudson Railroad also passes very close by (2000 ft., 0.6 km., away).

SITE PREPARATION REQUIRED: Tree felling and possibly grading will be required prior to construction.

ADVANTAGES: It is easily accessible, should have good soil, and should not be disruptive to neighboring land uses.

DISADVANTAGES: Portions of the site, or lands very close by, might be wet. A dense tree cover must be cleared.

Note: Directly across the river is another potentially suitable site on an outwash terrace. There appears to be a campground immediately uphill from the tract.

SCHROON LAKE QUADRANGLE

Two-thirds of the land is State-owned, forming a solid band across the central and northwestern parts of the quadrangle. Much of the northern region has terrain too rugged to build upon.

There is a large, level tract of undeveloped land between Olmsteadville and the Essex-Warren Co. border. It is dissected by small streams, however, and much of the ground appears on the photographs to be quite wet.

The corridors of the Northway (I87) and U.S. Route 9 occupy the eastern margin of the quadrangle. Possible sites are located in the north and eastern sections.

SCI

LOCATION: Four miles (6.4 km.) west of the Village of Schroon Lake off Hoffman Rd., near Lenardsville Rd. (Figure 16.)

EXISTING LAND USE/

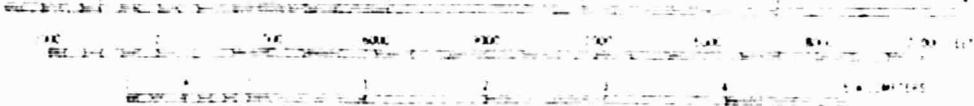
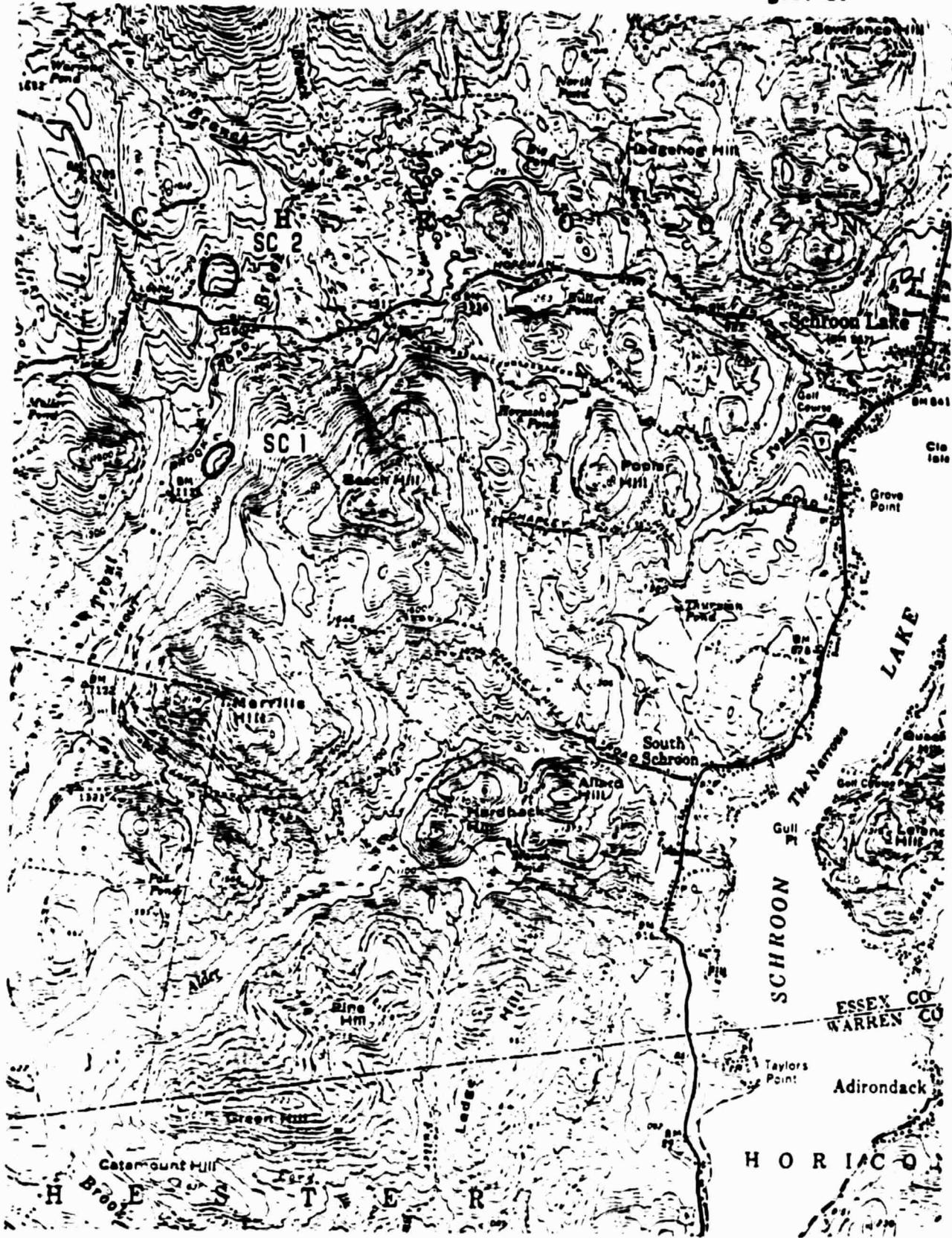
GROUND COVER: The tract had been cleared of trees in the recent past, either for agriculture or lumber. There are a few residences across the valley, approximately half a mile (0.8 km.) away.

SOILS: The proposed site is on a small terrace on the side of Beech Hill. Its airphoto appearance is well drained, but most of the land at slightly lower elevations between the site and Trout Brook are poorly drained. The soils map identifies it as of the Colton Association formed in glacial outwash. As such, the soils should be coarse grained with excellent engineering characteristics. The elevated topographic position should free it from drainage and flood problems.

SIZE: The boundaries of the site are defined by the wetlands on the west and steep ground on the east. The estimated amount of usable ground is 1.8×10^6 sq. ft. (0.17 sq. km.).

WATER: Ground water is likely to collect in this coarse-grained soil at the base of a crystalline hill. Surface water is in the form of Trout Brook, 1/4 mile (0.4 km.) away.

Figure 16



ORIGINAL PAGE IS
OF POOR QUALITY

ACCESSIBILITY: A stream must be crossed to connect the site with the road.

SITE PREPARATION REQUIRED: The tree cover is still thin from a previous clearing.

ADVANTAGES: It has been cleared and is close to the main road. The soil should be very good for construction. No agriculture is practiced on the site or nearby.

DISADVANTAGES: It is small, with wetlands surrounding its lower end. Construction may affect the few residences in the area.

SC2

LOCATION: Near Hoffman Road 4 1/2 miles (7.2 km.) west of the Village of Schroon Lake. (Figure 16.)

EXISTING LAND USE/

GROUND COVER: The tract is thinly wooded, having been cleared at some earlier time, apparently for agriculture.

SOILS: It is located on a broad terrace above Trout Brook. The airphoto tones are light, indicating dry soil conditions. The soil map designation is the Colton Association, coarse grained soils with excellent engineering characteristics and poor agricultural response, possibly explaining the abandoned farm. The site's elevated position will free it from drainage problems and its depth to bedrock should be fairly great.

SIZE: This site can be potentially very large, depending upon the amount of clearing and grading performed. The terrace is cut by the stream on the east, but rises for some distance until the hill becomes steep. Readily usable land is approximately 2.0×10^6 sq. ft. (0.19 sq. km.).

WATER: Ground water is likely to collect in the deep, coarse-grained soils.

ACCESSIBILITY: It is very close to Hoffman Rd. A short driveway would be required.

SITE PREPARATION REQUIRED: It has been cleared and is moderately level. Some grading would be necessary.

ADVANTAGES: It is close to the road, has good soil, and requires little preparation. Agriculture has already been tried but abandoned.

DISADVANTAGES: It might disrupt the remaining agriculture.

ORIGINAL PAGE IS
OF POOR QUALITY

SC3

LOCATION: Near Boreas Road, approximately one mile (1.6 km.) west of the hamlet of Blue Ridge and 4 miles (6.4 km.) west of exit 29 of the Northway. (Figure 17.)

EXISTING LAND USE/

GROUND COVER: A sand and gravel pit occupies part of the site. Surrounding lands are densely wooded. There are a few residences along nearby Boreas Road.

SOIL: The proposed site is on a terrace with an apparently deep soil cover. It appears to be well drained and should have soil of the Windsor Association, according to the soil map. Windsor soils are excessively drained, capable of supporting buildings on slopes of less than 8%, which holds true in this case. They generally have poor agricultural responses.

SIZE: The pit is currently less than 1×10^6 sq. ft. (0.9×10^5 sq. m.). Additional removal of sand and gravel would expand this.

WATER: Ground water may be plentiful in this coarse-grained soil. The Branch River passes nearby.

Figure 17



ORIGINAL PAGE IS
OF POOR QUALITY

ACCESSIBILITY: It is very easily accessible, being just 1/4 mile (0.4 km.)
from the main road and the Northway.

SITE PREPARATION REQUIRED: Reclamation of gravel pit.

ADVANTAGES: The soil, if any is left, should be good. The site is already
cleared and it is very accessible. Water should be available.

DISADVANTAGES: It is currently being used for sand and gravel extraction.
The soil cover may be exhausted when the operation is finished.

PARADOX LAKE QUADRANGLE

Virtually all of the land to the south of NYS Route 73 is State-owned, as is much of the land in the northwest quadrant. The valley north of Penfield Pond is occupied by the Hamlet of Ironville. Most of the dry land in and north of Ironville is being farmed.

With the exception of one location near the hamlet of North Hudson, the proposed sites are in the northeastern section of the quadrangle.

PL1

LOCATION: One mile (1.6 km.) south of Chilson, between Putts Pond and Armstrong Roads. It is five miles (8 km.) west of the Village of Ticonderoga, off NYS Route 74. (Figure 18.)

EXISTING LAND USE/

GROUND COVER: The tract is wooded, parts of it thinly so, as if it were once farmed and then abandoned. There are a few residences and small farms along Putts Pond and Armstrong Roads. There is an open excavation, possibly a sand and gravel pit on Putts Pond Road near the junction with Route 74.

SOIL: The proposed site is located on a portion of a till plain, at a slightly higher elevation (30-40 m.) than two streams that pass nearby. As such it should be quite well-drained. The Soils Map lists it as of the Parishville Association, a medium to coarse textured loamy soil derived from till. Shrinkage and swelling should be low, but a fragipan may interfere with drainage.

SIZE: The tract is bounded by two roads that form a V-shape. At the open end of the "V" is a wetland that would mark the limit of expansion. The approximate size is 10×10^6 sq. ft. (.93 sq. km.).

Figure 18



ORIGINAL PAGE IS
OF POOR QUALITY

WATER: Two streams pass within 1/4 mi. (0.4 km.) of the site. Ground water may be available.

ACCESSIBILITY: It is very easily accessible along either of the two roads.

SITE PREPARATION REQUIRED: The tree cover would require clearing, but part of the site had been cleared at one time and has only a thin tree cover

ADVANTAGES: It is hidden from the travel corridors, its soils should be adequate, and it is large.

DISADVANTAGES: Development may interfere with the neighboring residential land use. The fragipan might cause drainage problems.

PL2

LOCATION: Three miles (4.8 km.) northwest of Chilson on Lonesome Road, off of Corduroy Road. (Figure 18.)

EXISTING LAND USE/

GROUND COVER: The proposed site is cleared of trees, probably for a now defunct farm. One residence, perhaps the farm house, is near the site. The remainder of the land is wooded.

SOIL: Appears dry, although some nearby areas at lower elevations are wet. The General Soils Map designation is of the Becket-Peru Association, a soil formed in glacial till. The soil strength is fair and should be capable of supporting buildings. The low position and adjacent wetlands could lead to some drainage problems.

SIZE: Small; limited by adjacent wetlands and steep ground (0.6×10^6 sq. ft.; 0.05 sq. km.).

WATER: A stream passes by the site. The water table is probably high.

ACCESSIBILITY: It is close to NYS Route 73.

SITE PREPARATION REQUIRED: Little, because the ground is cleared of trees.

ADVANTAGES: It is completely hidden from travel corridors and has been cleared
of trees.

DISADVANTAGES: Drainage might be a problem.

PL3

LOCATION: 1.5 miles (2.4 km.) east of US 9 at North Hudson, just east of Johnson Pond.

EXISTING LAND USE/

GROUND COVER: The tract is thinly wooded, apparently once cleared for lumber. The surrounding areas are densely wooded.

SOIL: The proposed site is on the side of a hill that rises approximately 100 meters above Johnson Pond to the west and a swamp to the east. The soil tones are very light, indicating a dry soil. Its soil map listing is Becket-Peru, a medium-to-coarse textured loamy soil with a fragipan. Soil strength is fairly high and capable of supporting buildings, but the fragipan might interfere with the drainage.

SIZE: It is approximately 1.9×10^6 sq. ft. (1.8×10^5 sq. m.).

WATER: It is close to a large pond. Ground water is not very likely.

ACCESSIBILITY: A road leads directly to the site.

Figure 19



ORIGINAL PAGE IS
OF POOR QUALITY

SITE PREPARATION REQUIRED: The site has a very thin tree cover.

ADVANTAGES: It is the only available site in a largely State-owned region. It has been cleared for timber. No farming would be displaced.

DISADVANTAGES: It is somewhat isolated. Industrial use may interfere with the recreational use of Johnson Pond.

TICONDEROGA QUADRANGLE

Virtually none of the land in this quadrangle is State-owned. There are a few designated travel corridors that cross it: NYS Routes 9N, 22, 73, and 347. Development adjacent to these highways is discouraged. Most of the land in this quadrangle is relatively level and capable of sustaining industrial growth. It is also one of the most visible areas of the County, so questions of development here must be based upon societal goals rather than primarily physical constraints, as in much of the rest of the County.

The large area between Route 9N and Lake Champlain immediately northeast of the Village of Ticonderoga is almost entirely used for agriculture. Exceptions to this are the Ticonderoga Airport, Fort Ticonderoga, and a single large industry at the edge of the Lake. The soils are lakelaid clays, and are among the most suitable in the County for agriculture. In addition, the travel corridors of NYS Routes 9N and 22 afford a view of the Lake and the State of Vermont on the other side. Development in this area should be avoided.

Similarly, most of the dry land to the northeast of Crown Point is fertile clay soil that is currently being farmed. To the west of town appears to be a moderately dense residential area, with scattered farms.

Sites recommended for possible industrial development are on the rather droughty, infertile terraces that rise from the western edge of the lake plain.

T1

LOCATION: Four miles (6.4 km) southwest of Ticonderoga, off NYS Route 9N and Shattuck Road, on Lower Bull Rock Rd. (Figure 20.)

EXISTING LAND USE/

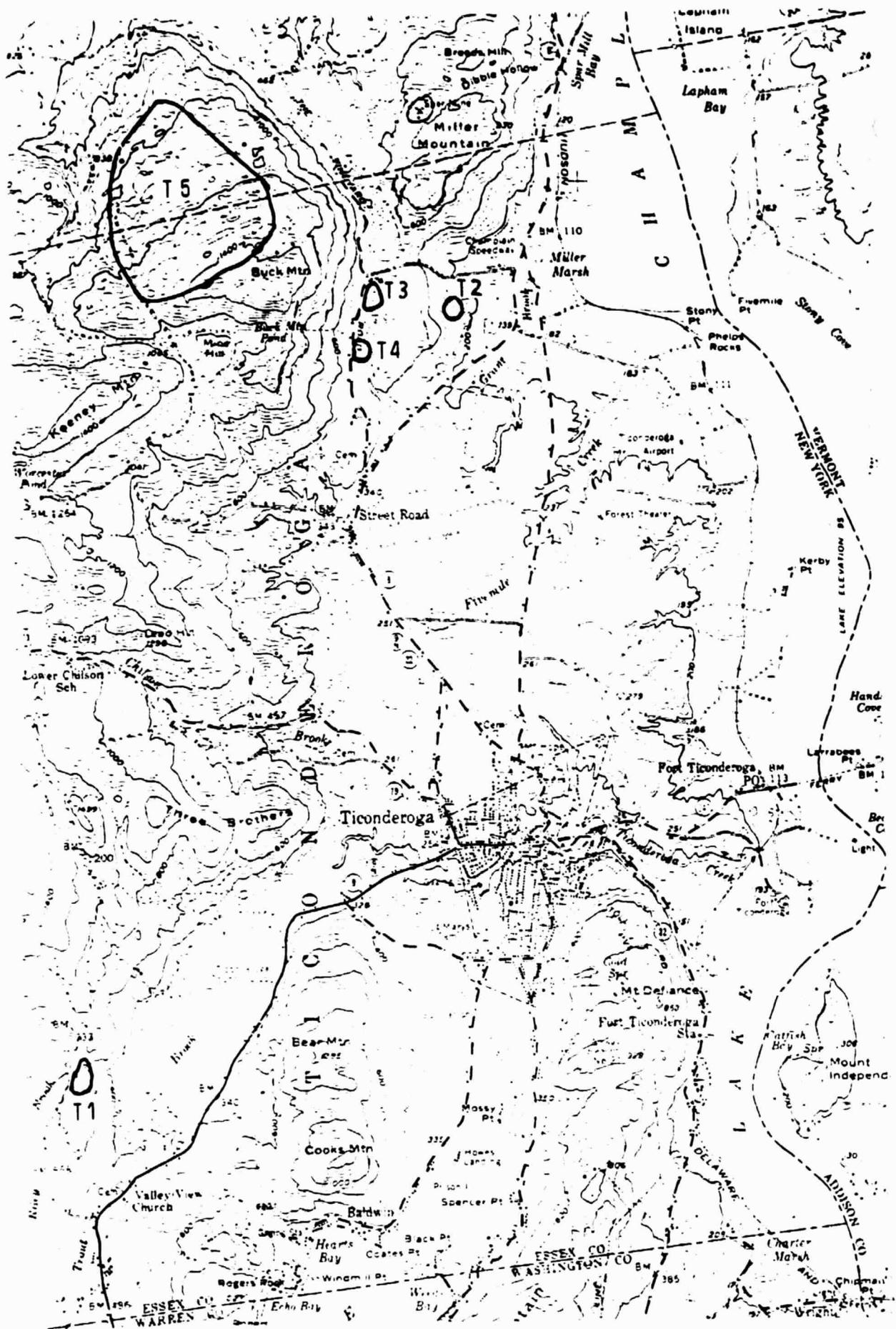
GROUND COVER: The proposed site is wooded, appearing to have once been cleared for agriculture. Adjacent tracts along Lower Bull Rock Road are currently being farmed.

SOILS: The land form is a terrace, presumably formed in outwash, and well-drained in appearance on the airphotos. It is likely to be of the Colton Association. Colton soils have excellent engineering properties and are generally poor agriculturally. The terrace location should provide a deep soil mantle, free from drainage problems.

SIZE: The land that is now not in agricultural use is approximately 0.9×10^6 sq. ft. (0.08 sq. km.).

WATER: Ground water should be available in this coarse-grained soil, especially given its position on a terrace, under which water moving downhill could collect. A stream (Riley Brook) flows near the contact between the terrace and the bedrock upland. It has cut down to a lower elevation than that of the proposed site, so it should not contribute to any drainage problems.

Figure 20



ACCESSIBILITY: It is very accessible, being only a mile (1.6 km.) from Route 9N.
Lower Bull Rock Rd. bisects the site.

SITE PREPARATION REQUIRED: Trees must be cleared. The site is level,
so very little grading would be required.

ADVANTAGES: It is very close to the highway corridor, yet probably not
visible from it. The soil should have excellent engineering
properties.

DISADVANTAGES: If too many trees are cleared it would be visible from
Route 9N. It might disrupt the adjacent agriculture.

T2

LOCATION: Midway between the Villages of Crown Pt. and Ticonderoga, just off of Routes 9N and 22. (Figure 20.)

EXISTING LAND USE/

GROUND COVER: There is an excavation, probably for sand and gravel, currently on the proposed site. It is surrounded by forests on three sides, with agriculture (possibly abandoned) on the fourth.

SOILS: The site is located on what appears to be an outwash terrace. The airphoto tones are very light, indicating a well-drained soil. This is borne out by the sand and gravel operation. The soil map identifies this site as having Colton Association Soils. Colton soils are very coarse-grained and have excellent engineering properties.

SIZE: The current size of the excavation is approximately 0.6×10^6 sq.ft. (0.05 sq. km.). This could be expanded somewhat, at the expense of the higher levels of the terrace.

WATER: Ground water should be available in this coarse-grained terrace, unless the excavation has interfered with the flow. Surface water is not visible nearby.

ACCESSIBILITY: Very good. It is about a kilometer from Routes 9N/22, but may actually be hidden from view behind what is left of the terrace.

SITE PREPARATION REQUIRED: The tree cover has already been cleared. Use of this site depends upon the operation of the sand and gravel pit. Reclamation would be required.

ADVANTAGES: The soil, if any is left, has excellent engineering characteristics. It is very close to a major travel corridor, but should be hidden from view. It would not displace any agriculture in a very intensively farmed area.

DISADVANTAGES: Any utilization of the site must wait for the extraction operations to halt.

T3

LOCATION: On the same terrace as site T2, but further uphill, to the west. It is adjacent to the Vineyard Road, and is also accessible from NYS Routes 9N/22. (Figure 20.)

EXISTING LAND USE/

GROUND COVER: An open excavation, probably a sand and gravel operation. A small farm is located just south of the site, on Vineyard Road. The remainder of the adjacent land is wooded.

SOIL: The soil appears to be very similar to that of site T2 and should have the same good engineering properties.

SIZE: It is approximately 0.6×10^6 sq.ft. (0.5×10^5 sq.m.).

WATER: It should have good ground water potential. No surface water is visible on or near the site.

ACCESSIBILITY: It is adjacent to the Vineyard Road.

SITE PREPARATION REQUIRED: Reclamation of the gravel pit.

ADVANTAGES: The soil appears to be excellently suited for construction; it is close to a major travel corridor, but is hidden from view.

DISADVANTAGES: Its use is dependent upon the termination of the extraction operations. The small farm on adjacent land might be adversely affected by industrial development.

T4

LOCATION: On the Vineyard Road, approximately 1/4 mile (0.4 km.) south
of site T3.

EXISTING LAND USE/

GROUND COVER: The actual proposed site is a cleared field, apparently an
abandoned farm plot. A small farm appears to be in operation
immediately north of the site.

SOIL: The soil is on the same large terrace as sites T2 and T3 and should
benefit from the same excellent Colton soils.

SIZE: It is approximately 0.6×10^6 sq. ft. (0.5×10^5 sq. m.).

WATER: Ground water should be available. No surface water is visible.

ACCESSIBILITY: It is easily accessible from U.S. 9 via the Vineyard Road
which passes alongside of the site.

SITE PREPARATION REQUIRED: Virtually none.

ADVANTAGES: The soil should be excellent for construction. It is hidden,
yet accessible. The land is cleared and level.

DISADVANTAGES: Development may adversely affect the small farm on the
adjacent tract of land.

LOCATION: South of Crown Point Center, just northwest of Buck Mountain.
(Figure 20.)

EXISTING LAND USE/

GROUND COVER: The proposed site is wooded. There are some residences along the roads that lead to it. It is hidden from the Lake Champlain valley behind a mountain ridge.

SOIL: The soil map refers to this area as being of the Parishville Association.

It is located on the gentle back side of a mountain ridge and appears to have fairly deep, well-drained soil. Parishville soils are formed in glacial till, so their boulder content might be quite high, possibly creating added excavation expense. Their strengths are high and capable of supporting structures.

A few small streams cross the site, with the possibility of causing locally wet areas. The majority of this very large site seems to have no drainage problems.

SIZE: This amount of undeveloped land here is quite large (50.0 x 10⁶ sq. ft., 2.79 sq. km.). However, parts of the site may be wet and must be avoided.

WATER: Streams cross the site. Ground water is possible in this coarse textured soil.

ACCESSIBILITY: A road passes by the site.

SITE PREPARATION REQUIRED: The dense tree cover would need clearing.

ADVANTAGES: It is hidden from the valley, the site is potentially quite large, and the soils are suitable for construction.

DISADVANTAGES: Much of the site may be wet. A dense tree cover would need clearing.

Comparison of the Sites

Site ^a	Engineering ^b Soil Quality	Water Availability		Land Use ^c	Accessibility ^d	Visibility ^e	Size ^f	
		Surface	Ground				x 10 ⁶ sq.ft.	x 10 ⁶ sq.m.
SL 1	Fair	X		Abandoned agr.	Very good	Low	3.3	3.1
SL 2	Fair	X		Wooded	Good	Moderate	1.2	1.1
SL 3	Fair	X		Wooded	Good	Moderate	2.7	2.5
LP 1	Excellent		X	Gravel pit	Very good	Low	2.2	2.1
LP 2	Very good		poss.	Thinly wooded	Very good	Moderate	2.0	1.9
LP 3	Very good	X	poss.	Wooded	Very good	Moderate	20.0	18.6
LP 4	Very good	X	poss.	Thinly wooded	Very good	Moderate	1.4	1.3
LP 5	Good	X	X	Abandoned agr.	Very good	Moderate	1.4	1.3
LP 6	Very good		poss.	Thinly wooded	Good	Low	1.6	1.5
LP 7	Excellent	X	X	Wooded	Fair	Moderate	2.0	1.9
Au 1	Good		X	Extraction	Very good	Moderate	2.0	1.9
Au 2	Good		X	Wooded	Good	Low	2.2	2.1
Au 3	Good		X	Thinly wooded	Very good	Low	2.2	
Au 4	Good		X	Abandoned agr.	Very good	Moderate	1.2	1.1
Au 5	Excellent	X	X	Gravel Pit	Excellent	Low	2.4	2.3
Au 6	Excellent	X	X	Wooded	Very good	Low	1.7	1.6
SA 1	Excellent	X	X	Thinly wooded	Fair	Low	2.3	2.2
SA 2	Good	X	X	Wooded	Very good	Low	12.8	11.9
MM 1	Very good	X	X	Wooded	Good	Low	18.3	17.0
MM 1A	Very good	X	X	Wooded	Good	Low	3.6	3.4
MM 2	Excellent	X	X	Agriculture	Good	Low	4.1	3.9
E 1	Excellent		X	Abandoned agr.	Very good	Low	2.0	1.9
PH 1	Excellent		X	Gravel pit	Very good	Low	2.2	2.1
PH 2	Excellent		X	Gravel pit	Very good	Moderate	1.5	1.4
N 1	Good	X	poss.	Thinly wooded	Fair	Moderate	1.0	0.9

Comparison of the Sites (continued)

Site ^a	Engineering ^b Soil Quality	Water Availability		Land Use ^c	Accessibility ^d	Visibility ^e	Size ^f	
		Surface	Ground				x 10 ⁶ sq.ft.	x 10 ⁵ sq.m.
N 2	Good	X	poss.	Cleared lot	Good	Low	1.3	1.2
N 3	Excellent	X	X	Wooded	Very good	Low	3.2	3.0
SC 1	Excellent	X	X	Cleared lot	Very good	Moderate	1.8	1.7
SC 2	Excellent	X	X	Thinly wooded	Very good	Moderate	2.0	1.9
SC 3	Good	X	X	Gravel pit	Very good	Low	1.0	0.9
PL 1	Good	X	poss.	Wooded	Very good	Low	10.0	9.3
PL 2	Fair	X		Abandoned agr.	Good	Low	0.6	0.5
PL 3	Fair	X		Thinly wooded	Good	Low	1.9	1.8
T 1	Excellent	X	X	Wooded	Very good	Moderate	0.9	0.8
T 2	Excellent		X	Gravel pit	Excellent	Low	0.6	0.5
T 3	Excellent		X	Gravel pit	Excellent	Low	0.6	0.5
T 4	Excellent		X	Abandoned agr.	Excellent	Low	0.6	0.5
T 5	Good	X	X	Wooded	Very good	Low	30.0	27.9

a. Shown on map, Figure 1, p. 22.

b. Based upon the soil's shear and bearing strengths and drainage characteristics; on site checks are required to confirm these characterizations.

c. From high altitude photographs obtained June 25, 1979.

d. This rating is based upon such factors as: proximity to villages, to highways and other travel corridors, and to rail links; whether or not an access driveway must be constructed; steepness of access road; presence of water bodies or wetlands to be crossed. The terms are relative, ranging from excellent (less than a mile from a population center) to fair (several miles from highway or town.)

e. Since no locations that have high visibility were selected, all sites are classified as having either "low" or "moderate" visibility. Sites with low visibility cannot be seen from highways or villages. Sites with moderate visibility may be visible under certain circumstances--e.g., if the buildings are tall, or if trees are cleared. Visibility was determined from the high altitude photographs.

f. 10⁶ sq. ft. equals approximately 23 acres. 10⁵ sq. m. equals 10 hectares.

OVERLAY 1: STATE- OWNED LAND

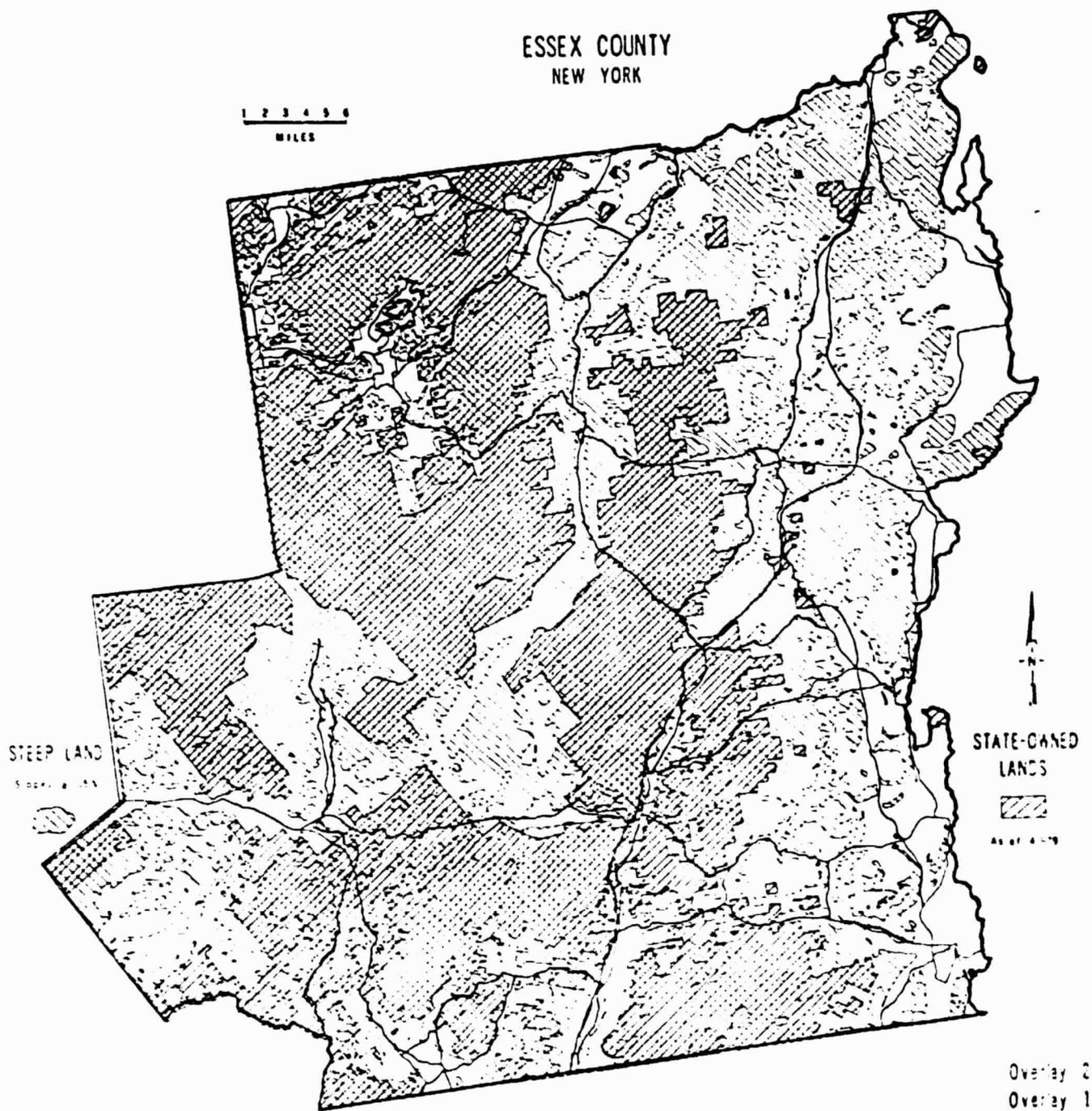
The intention of the State Legislature has been to gradually expand the State's ownership of land within the Adirondack Park. The format of the overlays, with their progressive elimination of lands from consideration, lends itself to the addition of future State purchases of land. For example, during the period between 1977 (which coincides with one of the reference maps used) and 1979 (which corresponds to the updated version of the map used) the State added several large and small parcels of land to its ownership. These were simply added to the cross-hatched areas on the overlay. Thus, this portion of the site selection model can be easily adaptable to such changes. (Another overlay, that of the steeply-sloped areas, should not have to contend with any real changes during its lifetime.) A full-sized paper copy of this overlay is included in the pocket on the back cover of this report. The overlay (2) to figure 21 is a reduction copy.

OVERLAY 2: STEEP LAND

The areas cross-hatched on this transparency are those with slopes of the 15% or greater. Also included on this overlay are those areas that have an elevation of greater than 2500 ft. (762 m.) although their local reliefs may be low.

The areas shown here were measured on 16 USGS topographic sheets and were combined at the common base map scale of 1:125,000. A full-sized copy of this overlay is in the pocket. The overlay to figure 21 is a further reduction in scale of the steep land map.

Figure 21



ORIGINAL PAGE IS
OF POOR QUALITY

BIBLIOGRAPHY

- "Adirondack Park Land Use and Development Plan Map," Adirondack Park Agency, Ray Brook, N.Y., April 1, 1979.
- "Adirondack Park State Land Master Plan," Adirondack Park Agency, Ray Brook, N.Y., June 1, 1972.
- Bernstein, Burton, The Sticks, A Profile of Essex County, N.Y., New York, N.Y., Dodd, Mead & Co., 1972.
- Bloomer, Robert O. and Elberty, William, The Adirondack Region: 3 Billion Years in the Making, St. Lawrence University, Office of Technical Services, Bulletin No. 1, 1967.
- "Development in the Adirondack Park," Adirondack Park Agency, Ray Brook, N.Y., April, 1977.
- Feurer, Reeshon, Garman, William L., and Cline, Marlin, "Soils of Essex County, N.Y.," New York State College of Agriculture, Cornell University, Ithaca, N.Y., 1955.
- The Future of the Adirondacks, Vol. II, The Technical Reports, Temporary Study Commission on the Future of the Adirondacks, Blue Mountain Lake, N.Y., The Adirondack Museum, 1971.
- Giese, G.L. and Hobba, W.A., Jr., Water Resources of the Champlain-Upper Hudson Basins, Albany, N.Y., New York Office of Planning Coordination, 1970.
- Heath, Ralph C., "Ground Water in New York," State of New York Conservation Department, Water Resources Commission, Bulletin GW-51, Albany, N.Y., 1964.
- Hyde, Floy S., Adirondack Forest, Fields, and Mines, Lakemont, N.Y., North Country Books, 1974.
- Kemp, James Furman, and Ruedeman, Rudolf, Geology of the Elizabethtown and Port Henry Quadrangles, New York State Museum Bulletin, No. 138, Albany, University of the State of New York, 1910.
- Kudish, Michael, Paul Smith's Flora, Saranac Lake, N.Y., Currier Press, 1975.
- Land Use Controls in New York State, The Natural Resources Defense Council, Inc., New York, N.Y., The Dial Press, 1975, pp. 106-131.
- Merrill, J.H. and Kemp, J.F., The Geology of the Moriah and Westport Townships, Essex County, N.Y., New York State Museum Bulletin, No. 138, Albany, University of the State of New York, 1895.

Murtha, Peter A. and McNeil, Richard J., "The Forest Preserve," in Current Topics in Conservation, Series II, No. 7, Ithaca, N.Y., Cornell University, 1966.

Olson, Gerald W., "Using Soil Surveys for Problems of the Expanding Population in New York State," New York State College of Agriculture and Life Sciences, Cornell University, Extension Bulletin 1123, Ithaca, N.Y., 1974.

Olson, Gerald W. and Warner, John W., "Engineering Soil Survey Interpretations," New York State College of Agriculture and Life Sciences, Cornell University, Information Bulletin 77, Ithaca, N.Y., 1974.

"Soil Survey Interpretations of Soils in New York State,"
Dept. of Agronomy, Cornell University and USDA, Ithaca, N.Y., 1972.

Watson, Winslow C., The Military and Civil History of the County of Essex, N.Y., Albany, N.Y., J. Munsell, 1869.

N8 I-25459

APPENDIX E

Research Papers

Civil Engineering Applications of

REMOTE SENSING

Proceedings of the Specialty Conference
of the Aerospace Division of the
American Society of Civil Engineers

University of Wisconsin
Madison, Wisconsin
August 13-14, 1980

Co-sponsored by
the American Society of Civil Engineers
the American Society of Photogrammetry
The University of Wisconsin

Ralph W. Kiefer, Editor



Published by the
American Society of Civil Engineers
345 East 47th Street
New York, New York 10017

ANALYSIS OF LANDFILLS WITH HISTORIC AIRPHOTOS

Thomas L. Erb¹, Warren R. Philipson², M. ASCE,
William L. Teng³, and Ta Liang⁴

ABSTRACT

The nature of landfill-related information that can be derived from existing, or "historic," aerial photographs, is reviewed. This information can be used for conducting temporal assessments of landfill existence, land use and land cover, and the physical environment. As such, analysis of low cost, readily available aerial photographs can provide important, objective input to landfill inventories, assessing contamination or health hazards, planning corrective measures, planning waste collection and facilities, and developing on inactive landfills.

INTRODUCTION

The inventory and monitor of active and inactive landfills for environmental contamination has received much attention in the wake of several well-publicized health emergencies. The use of remote sensing techniques for landfill leachate monitoring and management has been documented (Souto-Maior, 1973; Garofalo and Wobber, 1974; Philipson and Sangrey, 1977; Sangrey and Philipson, 1979). Major emphasis in these studies has been placed on the use of newly acquired remote sensor data--data collected specifically for landfill monitoring. The purpose of this discussion is to examine the value of existing aerial photographs for all aspects of waste management, including landfill monitor.

"HISTORIC" AERIAL PHOTOGRAPHS

At least one date of aerial photographic coverage exists for the entire land area of the United States and most of the world. This coverage can normally be obtained at low cost from the organization which acquired the photography or, in the case of pre-1941 U.S. government aerial photography, from the National Archives. Most of the photography is panoramic, with stereoscopic coverage, 7x9 in (18x23 cm) or commonly 1:20,000.

¹Research Specialist, ²Assoc. Prof., ³Grad. Teach. Asst., & ⁴Prof., Civ. & Envir. Engrg., Cornell Univ., Ithaca, N.Y.

D5

This existing, or "historic," aerial photography is especially useful for landfill investigations. Specific activities that can be aided by information derived from historic aerial photographs are listed in Table 1, along with the relative value of the information. In particular, an *Inventory* will identify the active and inactive landfills in an area; *Assessing Contamination/Health Hazard* analyzes the flow of any leachate from the landfill, to identify possible environmental damage or health endangerment; *Planning Corrective Measures* guides officials in the development of strategies for abatement of leachate contamination; *Planning Waste Collection and Facilities* anticipates changes in the generation and disposal of waste; *Developing an Inactive Landfills* includes both knowingly and unknowingly developing an inactive landfill (e.g., for biogas extraction); and *Other* possible activities might include those related to research and development of improved landfilling operations, as well as those related to legal actions.

Table 1. Summary of the value of historic aerial photographs for landfill activities.

ACTIVITY	RELATIVE VALUE
Inventory	Critical
Assessing Contamination/Health Hazard	May be critical, especially if site has been altered
Planning Corrective Measures	May be critical, especially if site has been altered
Planning Waste Collection and Facilities	Of little value if new air-photos are available
Developing on Inactive Landfills	May be critical
Other	Variable

VALUE OF HISTORIC PHOTOS

For analyzing landfills, the availability of one or more dates of aerial photography permits a temporal assessment of: (1) existence information, (2) land use and land cover, and (3) the physical environment (Table 2).

Existence Information

Assessment of landfill existence includes documenting the location, extent and possible nature of a landfill. The dates, scales and quality of available aerial photographic coverage of the landfill will determine the extent to which a complete history of such existence information can actually be ascertained. Similarly, the capacity to extract in-

Table 2. Landfill-related information derivable from historic aerial photographs.

- . EXISTENCE location, extent & possible nature of landfill
- . LAND USE/LAND COVER natural and artificial
- . PHYSICAL ENVIRONMENT geology, soils and drainage

formation on the nature of waste materials in a landfill will depend on the ability to detect and identify features such as metal drums or abandoned vehicles.

One important use of historic aerial photographs for obtaining existence information involves inventorying landfills which are presently inactive and possibly developed with other land uses. In Figure 1, for example, it can be seen that a water-filled trench, in 1938, was being filled in 1951, and had been completely filled and the site developed by 1966. Little evidence of the landfill can be found in the most recent coverage.

Similarly, the value of historic aerial photographs for documenting landfill boundaries is shown in Figure 2, where the expansion of an active landfill is traced over a 40-year period.

Land Use and Land Cover

Existence information is, in essence, only one type of air-photo-derived information which can be obtained on land use/cover, on or near an active or inactive landfill. Clearly, historic aerial photographs can be analyzed to obtain general or detailed information on land use/cover.

The importance of recognizing land use and land use change is illustrated in Figure 1, where the specific dates and locations of landfilling versus the dates and locations of residential construction might be of major significance in assessing the possibilities of leachate-related health problems.

Recognizing that the parking facility for the recreational center pictured in Figure 3 was built on a landfill, which was formerly a gravel pit, is critical to the design of a leachate sampling scheme. With the gravel pit, one would expect a high likelihood of ground water contamination.

Physical Environment

As existence information is only one element of land use/cover, so too is land use/cover only one element of the physical environment, which includes the geology, soils and surface as well as subsurface drainage.

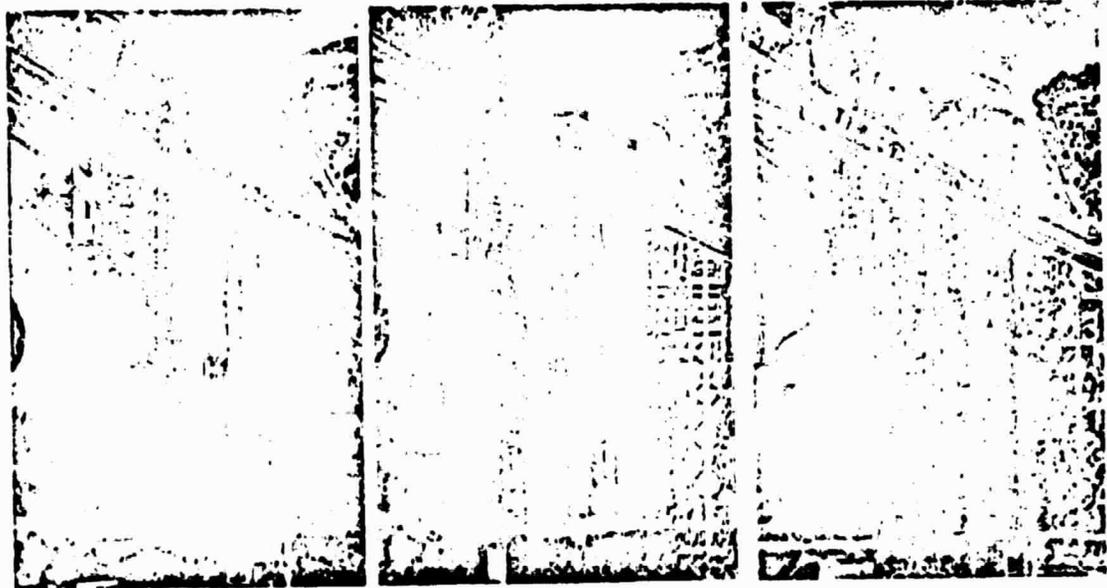


Figure 1. Historic aerial photographs of a landfill. Photographs were acquired in 1938 (top), 1951 (middle) and 1966 (bottom). Note water-filled trench, T, and current scars, S, in 1938.



Figure 2. Historic aerial photographs of a landfill. Photographs were acquired in 1938 (top), 1958 (middle) and 1978 (bottom). Note initial landfilling, L, and abandoned stream channel, A, in 1958.

This is evident with the last example (Fig. 3), where the gravel pit indicates the presence of subsurface granular materials. It is also evident in Figure 2, where with minimal airphoto interpretation skills, one can identify the abandoned stream channel and thus define a probable avenue for leachate movement. With a higher degree of airphoto interpretation in Figure 2, one could further characterize the area as being underlain by limestone (outcrops along stream, jointing, and other airphoto indicators). This type of bedrock is especially susceptible to ground water contamination.

A comparable or even greater degree of airphoto interpretation skills would be required to perform a comprehensive evaluation of the physical environment of the area pictured in Figure 1. Planning leachate detection and abatement must assess surface and subsurface drainage. In turn, this assessment must recognize the complex layering of fluvially reworked lakebed deposits, overlying dense glacial till, overlying the dolomitic bedrock. These interpretations can best be made from features appearing in the oldest photographs--features which are obscured or obliterated in more recent photographs (e.g., dark-toned current scars, in Fig. 1).

In general, historic aerial photographs can provide the most efficient and most complete source of information regarding the physical environment; moreover, in the absence of soil survey or surficial geology reports.

CONCLUSIONS

Analysis of existing, or "historic," aerial photographs can supply important, objective information for landfill investigations. Information pertaining to existence, land use and land cover, and the physical environment can be input to a wide range of landfill-related activities (Tables 1 and 2).

For Inventory--Historic aerial photographs may be the only source of reliable information.

For Assessing Contamination/Health Hazard--Analysis of historic aerial photographs can provide unique information, especially where the landfill and surrounding area have undergone substantial change (e.g., Figs. 1, 2 and 3). Analysis of historic photographs can also provide an excellent base for developing a systematic sampling plan for leachate contamination. As shown in Figure 1, information derived from the older photographs may indicate that new remotely sensed data (e.g., new aerial photographs) will be of relatively little value for assessing contamination.

For Planning Corrective Measures--Information derived through analysis of historic aerial photographs may be extremely important for planning corrective measures (e.g., Figs. 1, 2



Figure 3. Historic aerial photographs of a landfill. Photographs were acquired in 1938 (top) and 1979 (bottom). Note gravel pit, G, in 1938.

and 3). Normally, recent aerial photographic coverage is also required because of the need to relate remedial actions to existing land use and cover.

For Planning Waste Collection and Facilities--Aerial photographs are excellent sources of information for planning waste collection or new facilities; however, recent photographs are required because the area might have changed and be unavailable for development.

For Developing an Inactive Landfills--Any development on or of a known landfill site should be preceded by an analysis of historic aerial photographs of the site. The analysis may point out the extent of filling as well as other items of interest (e.g., nature of the fill). Additionally, any site or route selection problem which might inadvertently encounter a former landfill would also benefit from an analysis of historic coverage.

For Other Specific Landfill Investigations--Depending on the activity or purpose, the analysis of historic aerial photographs may be of real value or of little consequence.

In conclusion, information derived from historic aerial photographs is often invaluable. Although appreciable amounts of time may be required to locate, order, receive and catalog all available coverage of a site from U.S. Government as well as commercial agencies, only selected coverage may be required. In general, historic aerial photographs are readily available and, compared to the costs for acquiring field data or new aerial photography, they are inexpensive.

ACKNOWLEDGMENTS

This study was supported, in part, by the National Aeronautics and Space Administration (NASA Grant NGL 33-010-171) and the New York State Department of Health. Photographs used in the figures were flown by the U.S. Department of Agriculture, except for Figure 3 (bottom), which was flown by Lockwood Mapping Company, of Rochester, N.Y. The 1938 photographs are obtainable from the National Archives.

LITERATURE CITED

- Garofalo, D. and F. Wobber. 1974. Solid waste and remote sensing. *Photogrammetric Engineering* 40:2:45-59.
- Philipson, W.R. and D.A. Sangrey. 1977. Aerial detection techniques for landfill pollutants. In Proc. 3rd Annual EPA Research Symp. on Management of Gas & Leachate in Landfills. Held St. Louis. E.P.A., Washington, D.C. 11pp.
- Sangrey, D.A. and W.R. Philipson. 1979. Detecting landfill leachate contamination using remote sensors. Research Report EPA-600/4-7-060. E.P.A., Las Vegas, Nev. 67pp.

Souto-Maior, J. 1973. Applications of thermal remote sensing to detailed ground water studies. p. 284-298. In Proc. of Symp. on Remote Sensing and Water Resources Management. (K. Thomson, R. Lane & S. Csallany, eds.) Amer. Water Resources Assoc., Minneapolis, Minn.

TECHNICAL PAPERS

OF THE

AMERICAN SOCIETY OF PHOTOGRAMMETRY

FALL TECHNICAL MEETING

NIAGARA FALLS NY OCTOBER 7-10, 1980

LIBRARY OF CONGRESS CATALOG NUMBER

ISSN 0271-4040

Reproduction of this issue or any part thereof (except short quotations for use in preparation of technical and scientific papers) may be made only after obtaining the specific approval of the sponsoring society. Opinions or assertions expressed in the article do not necessarily represent the views of the American Society of Photogrammetry.

AMERICAN SOCIETY OF PHOTOGRAMMETRY
109 N. VIRGINIA AVE.
FALLS CHURCH, VA 22046

pages RS-3-D-1 to RS-3-D-10

MANUAL VERSUS DIGITAL LANDSAT ANALYSIS
FOR MODELING RIVER FLOODING

Warren R. Phillipson and William R. Hafker
Cornell University

Remote Sensing Program
School of Civil and Environmental Engineering
Hollister Hall
Ithaca, New York 14853

BIOGRAPHICAL SKETCHES

Warren R. Phillipson received his B.C.E., M.S. in Civil Engineering, and Ph.D. in Soil Science (Agronomy) from Cornell. Since 1965, he has taught, conducted research and participated in remote sensing projects in various parts of the world. An associate professor, he co-directs the Remote Sensing Program.

William R. Hafker received his B.S. with honors and distinction in Natural Resources and his M.S. in Aerial Photographic Studies and Remote Sensing from Cornell. He won the American Society of Photogrammetry's Bausch & Lomb Photogrammetric Award for the best paper by an undergraduate in 1978, the A.S.P.-Central New York Region Student of the Year Award in 1979, and the Legislative Council for Photogrammetry's scholarship for 1979.

ABSTRACT

The comparative value of manual versus digital image analysis for determining flood boundaries is being examined in a study of the use of Landsat data for modeling flooding of the Black River, in northern New York. The work is an extension of an earlier study in which Black River flooding was assessed through visually interpreted, multi-date Landsat band 7 images. Based on the results to date, it appears that new color-additive viewing nor digital analysis of Landsat data provide improvement in accuracy over visual analysis of band 7 images, for delineating boundaries of flood-affected areas.

INTRODUCTION

Similar to many other low gradient rivers, the Black River in northern New York floods regularly. Black River flood waters inundate farm land, breach roads, and cause annual damage which is estimated to exceed \$500,000 (Mayhew, 1979). Ground surveys of Black River flooding may be incomplete, however, and together with the existing topographic maps, they are inadequate for estimating agricultural and other losses. In general, ground surveys of flooding are difficult and costly to perform. The recurring problem in the Black River and similar basins is to determine the true extent of flooding in order that flood losses may be reliably estimated.

7 N81-20460

D-6

Various investigators have found that Landsat satellite data can be used effectively for delineating flood boundaries (e.g., Hallberg et al., 1973; Deutsch and Ruggles, 1974; Rohde et al., 1976; Sollers, 1978). McLeester and Phillipson (1979) extended these findings to the Black River in an attempt to model river flooding. They showed that flood boundary information derived from Landsat images, acquired at different flood stages, could be used to develop an empirical model for estimating the extent of flooding on the basis of in situ measurements of river discharge.

In their study of Black River flooding, McLeester and Phillipson (1979) derived all flood boundary information through visual analysis of Landsat band 7 (0.8-1.1 μ m) images. This was thought to be the most cost effective approach. The work described here was undertaken to determine whether improved results might have been obtained through digital image analysis or by including other Landsat spectral bands. In essence, if Landsat data are to be used for deriving flood boundary information: (1) are Landsat band 7 data adequate or should other Landsat spectral bands be examined, and (2) can visual image analysis provide sufficiently detailed and accurate information or should more costly digital image analyses be implemented?

METHODS AND MATERIALS

Study Area

The study area encompasses a highly flood-prone reach of the Black River in Lewis County, New York (Fig. 1). It extends approximately 65 km from Lyon Falls to Carthage, being depicted on six 1:24,000 scale, U.S. Geological Survey topographic maps (Brantingham, 1976; Carthage, 1943; Croghan, 1966; Glenfield, 1966; Lowville, 1966; W. Lowville, 1954). This area is known locally as the "Black River Flats" because the net change in river elevation for the entire reach is only three meters. From Carthage to Lowville, the width of the river valley varies from one to three kilometers, with levees less than one meter above low river flow. Vegetation is absent or without foliage through most of the spring flood season, allowing generally unobstructed overhead monitoring of flood waters.

Flooding along a 35 km stretch of the Black River has been studied by the Buffalo U.S. Army Engineer District (1974), using previous high water marks from a single flood as input to a computer program for determining water surface profiles. Plotting of these profiles was based on interpolation of elevations from the available 10 ft (3 m) contour maps.

Remotely Sensing Data

Images and computer-compatible tapes of two Landsat scenes of the Black River were obtained for analysis. One scene had been acquired during a period of normal river flow (11 October, scene #8108015180500); the second scene had been acquired during a flood stage, when the flood waters extended laterally approximately one kilometer (15 April 1977; scene #8281414491500).

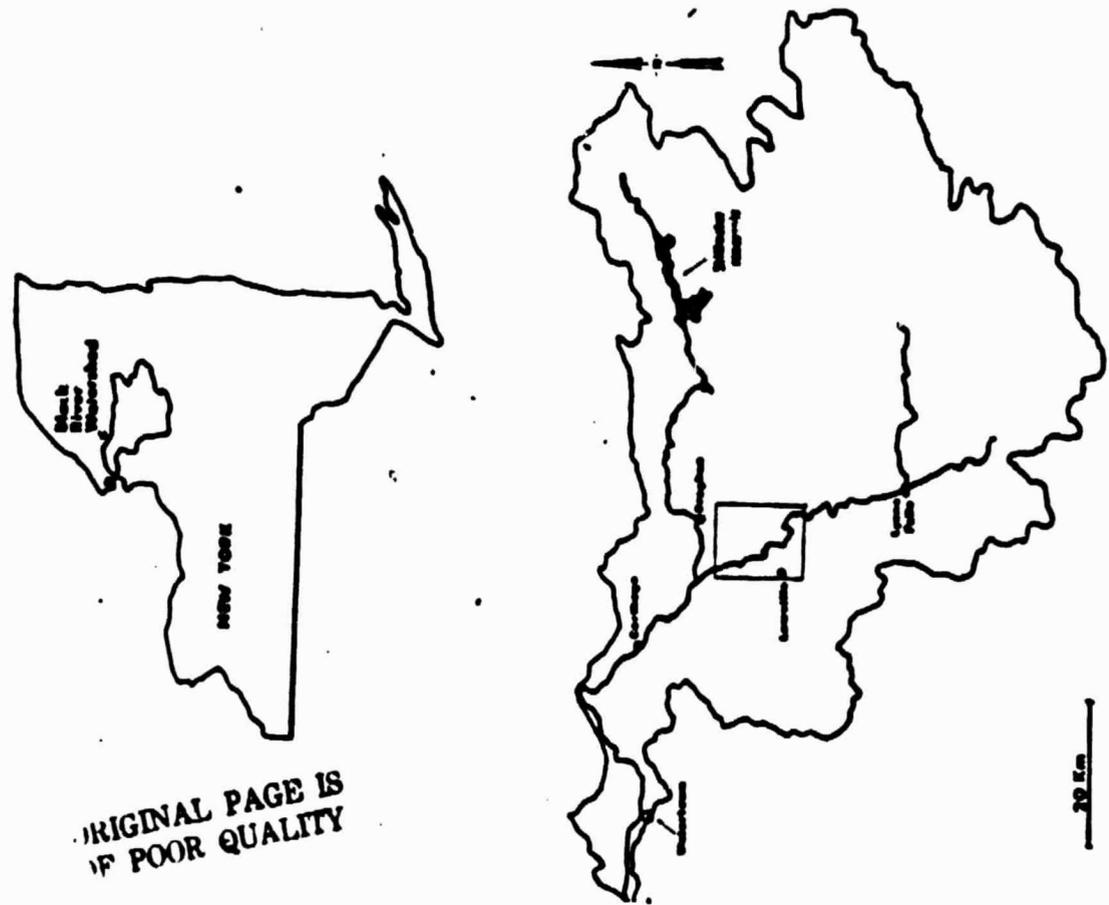


Figure 1. Location of Black River watershed and Lowville Quadrangle in New York.

ORIGINAL PAGE IS
OF POOR QUALITY

Aerial photographs of the portion of the Black River depicted on one U.S. Geological Survey topographic map, the Lowville Quadrangle, were also obtained for analysis (Fig. 1). These stereoscopic, 1:19,000 scale, panchromatic, 23 cm transparents had been flown by the U.S. Air Force, Rome Air Development Center during a flood period on 6 May 1971. Although the photography and the 15 April 1977 Landsat scene were not concurrent, the extent of flooding associated with the previous peak flows were comparable. The aerial photographs were acquired during a net river discharge of 16,930 cfs, following a peak discharge of 18,340 cfs by two days; the Landsat scene was acquired during a net river discharge of 13,970 cfs, following a peak discharge of 20,900 cfs by 14 days. (All discharge measurements were taken at Watertown, N.Y., and adjusted for flow from the Stillwater Reservoir and the time delay from Lowville.)

A 15 April 1977 meteorologic satellite image, acquired with the NOAA/TOS VHRR-IR sensor, was also examined; however, the spatial resolution of this image was inadequate for assessing the relatively narrow flood waters of the Black River.

Image Analysis and Information Extraction

Two bases for comparison of flood boundary information were established in the form of acetate overlays to the Lowville, 1:24,000 scale, U.S. Geological Survey topographic map (Fig. 1). The first was an overlay of visually interpreted flood boundaries derived through analysis of the 15 April 1977 Landsat band 7 image. This overlay, compiled for the earlier study by McLeester and Philipson (1979), was produced by enlarging the original 70 mm Landsat image to a 3x4 in (7.6x10 cm) projection plate, which was subsequently projected to a scale of 1:84,000 on a rear-view projection screen. The interpreted flood boundaries were delineated on a sheet of matte acetate at this scale and later enlarged to the final 1:24,000 scale map overlay using a Zoom Transfer Scope.

The second base for comparison of flood boundary information was a 1:24,000 scale map overlay of flooding conditions, interpreted from the 6 May 1971 aerial photographs. Using a light table, zoom stereoscope, and subsequently a Zoom Transfer Scope, the second author delineated four mapping units: water, wet areas (previously flooded), wet areas with taller vegetation, and areas unaffected by flooding. The location of the river channel was also mapped through interpretation of tree lines, exposed levees, and other indicators.

The airphoto-derived map overlay and the map overlay derived through visual analysis of the 15 April 1977 Landsat band 7 image were compared to each other and to other flood boundary products derived from the 15 April 1977 Landsat scene. These other products were derived through color-additive viewing and through digital analysis.

For color-additive viewing, the positive, 70 mm transparencies of the 15 April 1977 (flood) Landsat bands 4, 5 and 7 images were projected along with the positive, 70 mm transparency of the 11 October 1972 (no flood) Landsat band 7

image. Also analyzed were positive and negative transparencies of these images, photographically enlarged to three times their original scale. Various color filter-spectral band combinations were examined, including those recommended by other investigators (Deutsch and Ruggles, 1974). The combinations judged most informative were photographed directly from the screen of the color-additive viewer, and the resulting color slides were projected onto the 1:24,000 scale, base map overlays described above.

For the digital analysis, a 20 km stretch of the Black River, including that portion within the Lowville Quadrangle, was selected from the 15 April 1977 Landsat scene. The total lateral coverage of the subset study area varied from three to five kilometers.

The analysis was performed using the 1977 version of ORSER (Borden et al., 1977), modified for operation on Cornell's IBM 370/168 computer. In brief, brightness maps (NMAPs) of the subset area were produced; test sites (training areas) for "water," "wet areas (previously flooded)," and "wet areas with taller vegetation" were selected; statistics (STATS) characterizing the spectral response of the test sites were generated for each of Landsat's four spectral bands; and, using the test site statistics, a classification routine was implemented. The classifier (CLASS) categorizes pixels on the basis of their "nearness" to the statistical means established by the test site spectral values.

Selection of additional test sites and refinements to test site boundaries produced improvements in the classification. Further, in order to address the study objectives, classifications were based separately on all spectral bands, bands 5 and 7, and band 7 only.

RESULTS AND DISCUSSION

The location of the Black River in New York is shown in Figure 1, and the flood-affected area interpreted from the 15 April 1977 Landsat band 7 image is shown in Figure 2.

As described, two 1:24,000 scale map overlays depicting flood boundary information in the Lowville Quadrangle were produced; the first through visual analysis of the 15 April 1977 Landsat band 7 image, and the second through interpretation of the 6 May 1971 aerial photographs. Based on the respective previous peak discharges and the time elapsed since the peak, flood conditions on the two dates were judged to be similar. The information derived from the satellite and aircraft imagery was also found to be similar. Flood boundaries from the two map overlays generally differed by less than 100 m on the ground, with flood-affected areas differing by only 3%.

Color-additive viewing of positive and negative spectral images of the 15 April 1977 (flood) Landsat scene, with and without the 11 October 1972 (no flood) Landsat scene, produced few flood boundary differences from those derived through visual analysis of the Landsat band 7 images alone. Although the boundaries of the flood-affected area were nearly identical, tonal differences within the flood-affected

area could be observed with the different spectral images. These might be associated with turbidity patterns or flooding conditions (e.g., water versus wet areas). Ground or aircraft data, acquired concurrently with the Landsat data, would be needed to determine the true cause of the tonal differences.

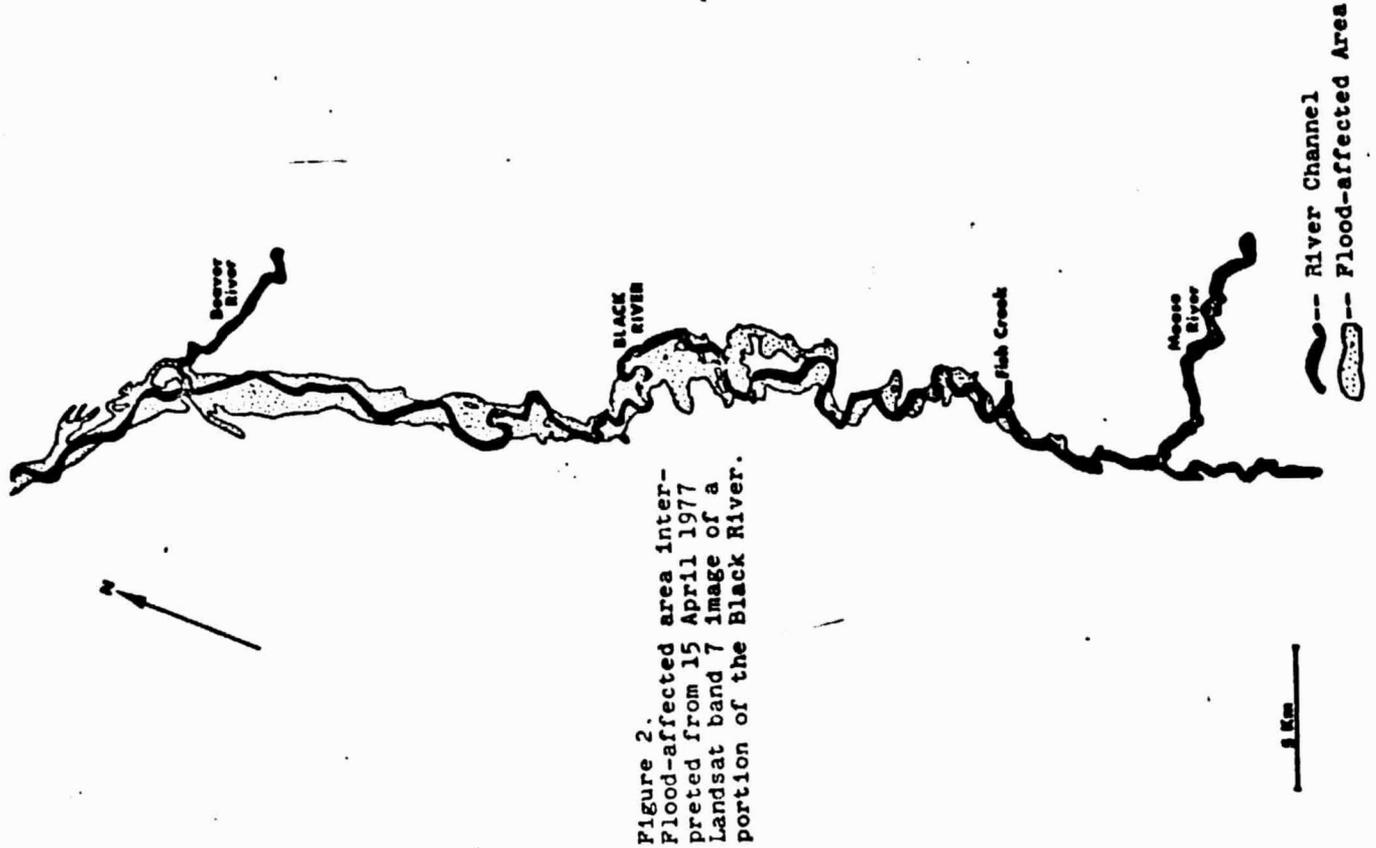
The results of the digital analysis of the 15 April 1977 Landsat scene are summarized in the table. As recorded, a total of 2,420 Landsat pixels were included within the flood boundaries derived from the aerial photographs, and 2,500 Landsat pixels were included within the flood boundaries derived through visual analysis of the Landsat band 7 image. These numbers were determined by superimposing the flood boundary overlays on geometrically corrected Landsat printouts (e.g., Fig. 3).

COMPARATIVE ACCURACY OF CLASSIFYING FLOOD-AFFECTED AREAS USING A SUPERVISED CLASSIFIER WITH DIFFERENT LANDSAT SPECTRAL BANDS

METHOD OF DELINEATING FLOOD BOUNDARIES	TOTAL NUMBER LANDSAT PIXELS W/IN FLOOD BOUNDARIES	PERCENTAGE OF LANDSAT PIXELS CLASSIFIED AS FLOOD-AFFECTED	
		ALL BANDS	BANDS 5&7
Interpretation of stereo air photos	2,420	68	94
Visual analysis of Landsat band 7 image	2,500	73	92

Supervised classification using band 7 and bands 5 and 7 produced printouts of flood-affected areas which were in excellent agreement with each other as well as with the flood boundary overlays. In contrast, the results of classification using all four spectral bands were not in close agreement with either the flood boundary overlays or the Landsat printouts (Fig. 3 and table).

Although these findings may be peculiar to this data set or to the Black River Basin, it appears that the inclusion of bands 4 and 6 in the classification process did more harm than good (cf., Hallberg et al., 1973). Moreover, classification with band 7 alone produced results which were at least as good as classification with bands 5 and 7 (table). Considering this and the close agreement between flood boundaries derived from aerial photographs and those derived through visual analysis of the Landsat band 7 image, there seems little justification for applying more costly digital analyses to flood boundary determination with Landsat data. To further verify this conclusion, Landsat computer-compatible tapes of different Black River flood scenes will be analyzed independently and with computer merging.



ACKNOWLEDGMENTS

Principal support for this investigation was through funds provided by the U.S. Department of the Interior, Office of Water Research and Technology, as authorized under the Water Research and Development Act of 1978 (Project No. A-089-NY). Partial support was also provided by Grant NGL 33-010-171 from the National Aeronautics and Space Administration.

REFERENCES

- Borden, F.Y., D.N. Applegate, B.J. Turner, B.F. Merembeck, E.G. Crenshaw, H.M. Lachowski, and D.N. Thompson. 1977. Satellite and aircraft multispectral scanner digital data users manual. OKSER, Penn. State Univ., Univ. Park, Pa. 294p.
- Deutsch, M. and P. Ruggles. 1974. Optical data processing and projected applications of the ERTS-1 imagery covering the 1973 Mississippi River Valley floods. Water Resources Bulletin 10:5:1023-1039.
- Hallberg, J.R., B.E. Hoyer, and A. Rango. 1973. Application of ERTS-1 imagery to flood inundation mapping. p.745-753. In Proc. Symp. Significant Results Obtained from the Earth Resources Technology Satellite-1. NASA SP-327. NASA, Washington, D.C.
- Mayhew, K.H. 1979. Personal communication. N.Y.S. Board of Hudson River-Black River Regulating District, Watertown, N.Y.
- McLeester, J.N. and W.R. Philipson. 1979. Developing in situ flood estimators using multi-date Landsat imagery. p.625-637. In Proc. 45th Ann. Mtg. Amer. Soc. Photogram., A.S.P., Falls Church, Va.
- Rohde, W.G., J.V. Taranik, and C.A. Nelson. 1976. Inventory and mapping of flood inundation using interactive digital image analysis techniques. p.131-143. In Proc. 2nd Ann. Wm. T. Pecora Memorial Symp. Amer. Soc. Photogram., Falls Church, Va.
- Sollers, S.C., A. Rango, and D.C. Henninger. 1978. Selecting reconnaissance strategies for floodplain surveys. Water Resources Bulletin 14:2:359-373.
- U.S. Army Engineer District, Buffalo. 1974. Flood Information report, Black River, New York, Carthage State Dam to Mill Creek near Lowville. Prepared for N.Y.S. Dept. Environ. Conservation. U.S. Army Corps Engrs., Buffalo, N.Y. 3p. + 23 plates.

USE OF REMOTE SENSING IN LANDSCAPE STRATIFICATION
FOR ENVIRONMENTAL IMPACT ASSESSMENT

John A. Stanturf
Remote Sensing Program
School of Civil and Environmental Engineering
Hollister Hall
Cornell University
Ithaca, New York 14853
(607) 256-4330

Douglas G. Heimbuch
Heimbuch-Stanturf, Inc.
119 W. King Road
Ithaca, New York 14850
(607) 277-4608

TECHNICAL PAPERS

OF THE

AMERICAN SOCIETY OF PHOTOGRAMMETRY

FALL TECHNICAL MEETING

NIAGARA FALLS NY OCTOBER 7-10, 1980

LIBRARY OF CONGRESS CATALOG NUMBER

ISSN 0271-4040

Reproduction of this issue or any part thereof (except short quotations for use in preparation of technical and scientific papers) may be made only after obtaining the specific approval of the sponsoring society. Opinions or assertions expressed in the article do not necessarily represent the views of the American Society of Photogrammetry.

AMERICAN SOCIETY OF PHOTOGRAMMETRY
105 N. VIRGINIA AVE.
FALLS CHURCH, VA 22046

ABSTRACT

Matrix approaches, in which environmental elements are arrayed against proposed activities, are frequently used in environmental impact assessment. A refinement to the matrix approach is to use landscape units in place of separate environmental elements in the analysis. These landscape units can be derived by mechanical overlay or quantitative techniques if single-factor maps are already available. When complete single-factor maps are not available at similar scales, landscape stratification is still possible. Landscape units can be delineated by integrating remotely sensed data and available single-factor data. This paper describes a remote sensing approach to landscape stratification and points out the conditions under which it is superior to other approaches that require single-factor maps. Flowcharts show the steps necessary to develop classification criteria, delineate units and a map legend, and use the landscape units in impact assessment. Application of the approach to assessing impacts of a transmission line is presented to illustrate the method.

BIOGRAPHICAL SKETCHES

John A. Stanturf is a research associate with the Remote Sensing Program, School of Civil and Environmental Engineering and Ph.D. candidate in Forest Soils, Department of Agronomy, Cornell University. Mr. Stanturf holds a M.S. in Soil Science, Cornell University and a B.S. in Agricultural Science, Montana State University, Bozeman. He has been a lecturer in Forest Soils at Cornell and an Assistant Soil Scientist with the Energy Planning Division, Montana Department of Natural Resources and Conservation. He is a member of the Society of American Foresters; Soil Science Society; Conservation Society; and International Society for Tropical Forestry.

Douglas G. Heimbuch is President of Heimbuch-Stanturf, Inc., a natural resource consulting firm with specialization in quantitative techniques for management under uncertainty. Mr. Heimbuch is a Ph.D. candidate in Fishery Science, De-

N81-25461

variations exist (e.g., Clark 1974). Schlesinger and Daetz (1973) suggest a more flexible use of the matrix than Leopold et al. (1971). The matrix is derived in successively more complete and complex versions as the project proceeds from planning through impact assessment.

If the study area is extensive, environmental attributes and impacts on them will vary by location. Direct application of the matrix approach in this instance would require a complete single factor data set at each location. Such an array typically is derived by overlaying geographically-based single factor data (Davis 1980; Steinitz et al. 1976). Except for attributes which can be assessed reliably at small scale, these maps are necessarily extrapolations of scarce data. Under these conditions, a refinement of the matrix/overlay approach is to use landscape classes in place of separate environmental elements in the analysis. A landscape class is a combination of environmental elements that will respond similarly to manipulation. Thus broad categories of vegetation or soils, for example, would be subordinate to specific landscape classes on the horizontal axis of the matrix (Fig. 3).

CONSTRUCTION PHASE PROJECT ACTIVITIES	ENVIRONMENTAL ATTRIBUTES											
	LANDFORMS LANDSCAPE CLASS			MOUNTAINS M-3-d			FOOTHILLS F-1-a			F-1-b		
RIGHT-OF-WAY CLEAR	M	M	M	M	S	S	M	S	S	M	S	M
FOUNDATIONS	M	M	S									
STAGING AREAS	M	M										
VEHICLE MOVEMENT	M		S									
HEAVY EQUIPMENT	M		S									

Figure 3. Part of a modified impact matrix for a transmission line, incorporating landscape classes. (M=moderately adverse impact, S=severely adverse impact.)

Deriving the landscape classes requires considerations of both intended manipulation and characteristics of the natural environment such as vegetation, soils and geology. A landscape class melds together "natural" classifications of landscapes and likely impacts of specific projects or types of activity. We have identified four classification methods suited to defining landscape units. These methods are multivariate statistical, overlay, ecological land classification, and integrated survey.

The method we refer to as ecological land classification is a generalization of the Canadian technique of the name (Thie and Ironside 1976; Bailey et al. 1978; Corliss 1974). The intention in using such a system is to integrate classification of separate environmental attributes into an hierarchical classification of the land scape. Integrated survey, most highly developed in Australia (Christian and Stewart 1964; Stewart 1968; Mitchell 1973), is also hierarchical and differs from ecological land classification in its data requirements. We prefer these landform-, or physiographic-, based systems because they are less demanding of detailed ground data than multivariate classifications (e.g., Gevritz and Powe 1977) and incorporate a knowledge of processes lacking when single-factor maps are mechanically overlaid. The Land Systems Inventory (Wertz and Arnold 1972) an ecological land classification, was used for the transmission line study.

CHOOSING THE BASE MAP

While the need for a base map is obvious, selection of a particular base map should include consideration of characteristics of other data. It's important that the scale of the base map be similar to the scales at which the other data were collected. Information content (i.e., extrapolated from few samples versus complete enumeration) and reliability (i.e., field observation versus expert opinion) of the data also affect the appropriateness of a base map.

If the entire study area is available at a single scale, the best maps are topographic since they are inexpensive, geometrically correct, and provide topographic as well as geographic information. Alternatively, Landsat color composites may be acceptable if the scale of Landsat is consistent with the scale of the other data. The advantages of Landsat as a base map are its availability and near-orthophoto quality (Liang and Philipson 1977). If this small scale is appropriate but Landsat is not available (for example in continuously cloudy areas) radar may be acceptable.

Photography should be considered when a larger scale is necessary. Orthophotos are really needed to provide a satisfactory base map, but they are not widely available. Semiconnected mosaics also can be used.

Highway maps are available in most places in North America and have their good points--geometric accuracy and some cultural landmarks--but points against are substantial--no topography and scales are usually either too small (whole state) or too large (just a county).

Existing interpretive maps should be avoided as base maps. Usually they are not published at an appropriate scale or don't provide enough landmarks to be of use. If they were not done on a geometrically accurate base, location errors are simply compounded when other data are projected to this scale.

For the transmission line study, only Landsat and 1:250,000 topographic maps were available for the entire area. Topo-

Table 1. Landscape Class Descriptions

Landform	Mountains	Foothills	
	Symbol	F-1-a	F-1-b
Name	Slumpy Mountains	Folded Sedimentary Foothills	Dissected Pediments
Precipitation	25-60"	10-14"	10-14"
Regime	Pacific Maritime	Continental	Continental
Description	Mid-elevation mountains, unstable geology	Steep smooth slopes of moderate relief	Gently sloping benches with steep breaks along drainages
Geology	Shales and Siltstones	Dipping consolidated Sedimentaries	Sandstones and Shales
Soils: Dominant Subgroups	Andic Cryochrepts, Udic Ustochrepts	Aridic, Lithic, and Typic Haploborolls, Torriorthents	Aridic Argiborolls, Haploborolls, Calciborolls
Soils: Dominant Families	Steep and very steep, loamy, skeletal	Hilly or steep, fine loamy and loamy, skeletal	Level to undulating, fine loamy and loamy, skeletal
Climax Vegetation	Douglas Fir, Alpine Fir, with inclusions of Cedar and Hemlock	Shortgrass Prairie and Sagebrush	Shortgrass Prairie and Sagebrush

Not surprisingly, a complete single factor data set did not exist for the transmission line study area. Large-scale aerial photography was available from the U.S. Forest Service. Other geobased information included soils, vegetation, geology, and precipitation maps, none of which existed for the entire area. In light of the limitations of the data, the method selected was ecological land classification. Criteria for definition of the landscape classes were developed at the landtype-level of Land Systems Inventory (Wendt et al. 1975; Wertz and Arnold 1972), modified by consideration of expected impact. The classification was for the particular project and was not meant to be a general landscape classification.

Classification criteria were established in consultation with disciplinary specialists on the study team, in other agencies, academics, and by air photo analysis. Five basic landforms initially were recognized: alluvial land, basins, foothills, mountains, and plains. The landforms were subdivided into landscape classes.

Each landscape class was given a code, described as to its physiographic characteristics and criteria for separation, and its component soils and vegetation. Some selected descriptions are given in Table 1.

An impact matrix was formulated using the landscape classes (Fig. 3). The classes were evaluated for limitations on roadbuilding and tower foundations; risk of sediment yield from soil erosion; slump hazard; and limitations on re-establishing vegetation.

STRATIFICATION OF THE STUDY AREA

The completed impact matrix provides a summary of the expected impacts of project activities in relation to the landscape classes, without regard to spatial location. Location of expected impacts can be determined by stratification of the study area. Stratification is based upon the criteria used to define landscape classes, and allows for a one-to-one mapping of impacts associated with landscape classes and locations in the study area.

Stratification can be done by manual or computer-assisted overlay or by photointerpretation. The method used will depend upon the nature of the data, or on the method used for classification which is based on the nature of the data. If classification was by a multivariate method applied to point data, stratification can be done by simple overlay of single factor maps (Steinitz et al. 1976). Otherwise, photointerpretation techniques can be used to extend known data to other areas.

If the overlay method was used to classify, it provides the stratification. If ecological land classification or integrated survey was used, the study area will be stratified using photointerpretation and supplemental data, or result directly from processing Landsat digital data.

For the transmission line study, the constraints of the data (availability of air photos and topographic maps and incomplete soils, vegetation, and other data) which led to the use of ecological land classification also dictated the method of stratification. The study area was stratified by airphoto-interpretation in conjunction with other data.

DISCUSSION

We haven't emphasized the details of the four classification methods. They are documented in the literature and we recommend the interested reader consult the references given. We have presented our method in a general way so that it can be adapted readily to specific projects. Further, we have stressed the relationship between classification methodologies and data limitations to show the utility of our modification of the ecological land classification method. Some items are simply enough stated but major undertakings in practice. Users are cautioned that too often their notions of appropriate and acceptable will be compromised by the availability and validity of existing data.

REFERENCES

- Bailey, R.G.; R.D. Pfister; and J.A. Henderson. 1978. Nature of land resource classification - a review. *J. Forestry* 76:650-655.
- Christian, C.S. and G.A. Stewart. 1964. Methodology of integrated surveys. In UNESCO Conf. Principles Methods Integrated Aerial Survey Studies. Nat. Resour. for Potential Development: 233-280. Toulouse, France.
- Clark, J. 1974. Coastal Ecosystems. Conservation Foundation, Washington, D.C.
- Corliss, J.C. 1974. ECOCLASS - A method for classifying ecosystems. In Foresters in Land Use Planning. Proc. 1973 Nat. Convention Soc. Amer. For. 7:264-271. Washington, D.C.
- Davis, L.S. 1980. Strategy for building a location - specific multi-purpose information system for wildland management. *J. Forestry* 78:402-408.
- Energy Planning Division. 1974. Draft EIS. 500KV electric transmission lines: Colstrip to Hot Springs. Montana Department Natural Resources and Conservation. Helena, Montana.
- Fischer, D.W. and G.S. Davies. 1973. An approach to assessing environmental impacts. *J. Environ. Manage.* 1:207-227.
- Gevirtz, J.L. and P.G. Rowe, 1977. Natural environmental impact assessment: a rational approach. *Environ. Manage.* 1:213-226.
- Leopold, L.B.; F.E. Clark; B.B. Hanshaw; J.B. Balsley. 1971. A procedure for evaluating environmental impact. U.S. Geological Survey Circular 645. Washington, D.C.

Liang, Ta and W.R. Philipson. 1977. The use of airphoto interpretation and remote sensing in soil resource inventories. In *Soil Resource Inventories*, Proc. of a workshop. Dept. of Agronomy Mimeo 77-23:115-122. Cornell Univ. Ithaca

McHarg, I. 1969. Design with nature. Doubleday Natural History Press. Garden City, N.J.

Mitchell, C. 1973. Terrain evaluation. Longmen Group Ltd. London.

Munnally, N.R. 1969. Integrated landscape analysis with radar imagery. *Remote Sensing of the Environ.* 1:1-16.

Schlesinger, B. and D. Daetz. 1973. A conceptual framework for applying environmental assessment matrix techniques. *J. Environ. Sci.* July/Aug.:11-16.

Sewell, W.R.D. 1973. Broadening the approach to evaluation in resources management decision-making. *J. Environ. Manage.* 1:33-60.

Steinitz, C. 1970. Landscape resource analysis. *Landscape Arch. Quart.* 60:101-105.

; P. Parker; J. Lawrie. 1976. Hand-drawn overlays: their history and prospective uses. *Landscape Arch.* Sept.:444-455.

Stewart, G.A. ed. 1968. Land evaluation. Macmillan Australia. Melbourne.

Thie, J. and G. Ironside, eds. 1976. Ecological (biophysical) land classification in Canada. Proc. First Mtng. Canada Comm. Ecological (Biophysical) Land Classification, 25-28 May 1976. Lands Directorate, Environment Canada, Ecological Land Classification Series No. 1. Ottawa.

Tryzna, T.C. 1974. Environmental impact requirements in the states-NEPA's offspring. *Environ. Prot. Agency EPA-600/5-74-006.* Washington, D.C.

Wendt, G.E.; R.A. Thompson; and K.N. Larson. 1975. Land systems inventory Boise National Forest. USDA Forest Service Intermountain Region. Ogden, Utah.

Wertz, W.A. and J.F. Arnold. 1972. Land systems inventory. USDA Forest Service Intermountain Region. Ogden, Utah.

ORIGINAL PAGE IS
OF POOR QUALITY

APPENDIX F

Selected Correspondence

June 18, 1980

P10.33

Dr. T. L. Erb
Cornell University
Ithaca, New York 14850

Dear Dr. Erb:

In the program for the ASCE Specialty Conference on remote sensing, to be held at the University of Wisconsin this August, you and colleagues from Cornell are scheduled to present a session on analyzing landfills with historic air photos. I am interested in this topic. Do you have any publications in the literature to which I can refer for more information?

We are actively engaged in landfill siting, operations, design and construction management, and are interested in techniques that can be applied to our work.

Thank you for your response.

Sincerely,

Rhea Lydia Graham

Rhea Lydia Graham
Engineering Geologist

RLG:cw:1804

**PURDUE
UNIVERSITY** LABORATORY FOR APPLICATIONS
OF REMOTE SENSING

August 25, 1980

SAMPLE REQUEST

Thomas L. Erb
Research Specialist
Cornell University
Hollister Hall
Ithaca, NY 14853

Dear Tom:

I wanted to thank you once again for a very interesting presentation at the ASP Conference last week in Madison. I certainly thought your example provided an excellent series of illustrations on the use of sequential aerial photography. As I had mentioned to you at the Conference, I would be very interested in obtaining copies of the slides, particularly the sequence showing the area that had previously been a gravel pit before the land fill operation and the other slides of the Love Canal. Such a series would add considerably to the unit I give both fall and spring semesters on Land Use Applications in my Remote Sensing courses.

I have enclosed a couple of articles describing some of the work with which we are involved here at Purdue. Once again, I enjoyed the opportunity meeting you and certainly thank you for your consideration of my request of the teaching materials.

Sincerely yours,



Roger M. Hoffer
Professor of Forestry, and
President, Western Great Lakes Region,
ASP

Enclosures



1220 Potter Drive
West Lafayette, Indiana 47906
(317) 749-2052

H. MOOIJ & ASSOCIATES

solid and hazardous waste management engineering

3 Elk Court, Kingston, Ontario, Canada, K7M 7A4. (613) 389-7720

November 14, 1980.

SAMPLE Request

Prof. T.L. Erb
Department of Civil Engineering
Cornell University
Ithaca, New York 14853.

Dear Sir:

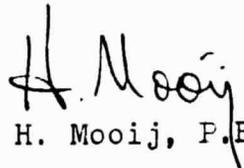
I would appreciate receiving a copy of your paper on the "Analysis of Landfills with Historic Airphotos" as presented at the ASCE/ASF Specialty Conference on Civil Engineering Applications of Remote Sensing, held at the University of Wisconsin in August of this year.

It would also be of interest for us to learn more about your own work in landfills. Any other references or papers you may have dealing with remote sensing applications to landfills would be of interest to us.

Thank you.

Yours truly,

H. MOOIJ & ASSOCIATES LTD.



H. Mooij, P.Eng.

HM/ej

Environmental Remote
Sensing Applications
Laboratory (ERSAL)



Corvallis, Oregon 97331 (503) 754-3056

SAMPLE REQUEST

October 9, 1980

Dr. Warren R. Philipson
Hollister Hall
Cornell University
Ithaca, NY 14853

Dear Dr. Philipson,

I am interested in obtaining more information on your project dealing with clear cut monitoring with remotely sensed data. We have initiated the same type of study in Oregon and would like to know what type of techniques you utilized as well as, the size of the clear cut studies and the interpretation accuracy encountered.

If Mr. Hafker's thesis is available as a published report or as a xerox copy, please send me a copy and a bill covering the cost of the document.

Sincerely,

Anthony J. Lewis
Anthony J. Lewis
Research Associate

AJL/ja



ENVIRONMENT

Environmental Coordination Services

403/427-2381

Alberta Remote Sensing Center

Telex 037-2006. TWX 610-831-2636

11th Floor, Oxbridge Place

9820 - 106 Street

Edmonton, Alberta, Canada

T5K 2J6

SAMPLE REQUEST

21 October, 1980

Dr. W. R. Philipson
Cornell University
Hollister Hall
ITHACA, N.Y. 14853

Dear Sir,

I would appreciate it if you would send me more information regarding the monitoring of forest clearcutting. While conventional, large scale photography is currently used here, a number of forest products companies have expressed interest in the use of small scale photography or Landsat imagery for cut-over mapping.

Thanks for your assistance.

Yours sincerely,

Robert Morton

Robert Morton

RM/hg

MEMBERS OF COMMISSION

JANE T. BOWMAN
BLANCHE M. GREENE
URBAN N. KARCHER
LIVINGSTON LANSING
BERNARD E. MALONEY
JAMES M. McMAHON
WILLIAM J. TAYLOR

State of New York
Temporary State Commission
on Tug Hill
N.Y.S. Office Building
317 Washington Street
Watertown, New York, 13601
(315) 782-0100

RICHARD E. MARK
Chairman

STEPHEN L. RICH
Secretary

BENJAMIN P. COE
Executive Director

July 16, 1980

Mr. Warren Philipson
Remote Sensing Program
464 Hollister Hall
Cornell University
Ithaca, New York 14850

Dear Mr. Philipson:

For the past several years the Tug Hill Commission has been keenly interested and quite active in recognizing the potential of wind power in the Eastern Ontario - Tug Hill area. In 1974 the Commission sponsored site specific wind studies in and around the Tug Hill area.

On July 10 Robert Quinn and I met with Paul Wendelgass (SEO) and Bruce Bailey (SUNY ASRC) to discover any new developments in the New York wind energy scene and to convey the Commission's interest in this field. Paul and Bruce made reference to your work in Erie, Niagara, and Orleans counties. We would greatly appreciate any information you could provide us on your research out there. Bob and I were also informed that your analysis might be completed by fall 1980. If so what would be the possibility of identifying prospective Tug Hill wind sites using the remote sensing technique? Both Bruce and Paul feel confident that there exist some good sites in this area.

We were also informed of Cornell's anemometer loan program and that this program is currently operating in Erie, Niagara, and Orleans counties. Do you have an idea as to who to contact regarding this program?

Thanks very much for your time. We look forward to hearing from you soon.

Sincerely,



Hugh Porter
Policy Analyst

HP/cf

September 18, 1980

MEMORANDUM

TO: All Planning Departments
All Environmental Protection Agencies

FROM:

David Newton

David F. Newton
COOPERATIVE EXTENSION AGENT
Land Use Specialist

We've been asked by the School of Civil and Environmental Engineering at Cornell University to inform you about the School's Remote Sensing Program. Working under a grant from NASA, the School is seeking new, problem-solving applications of aircraft and satellite remote sensing in New York State. Some specifics about this program are explained on the reverse side of this letter. The projects have been, and must continue to be, action- or benefit-producing, unique in some way, and normally rely on existing aircraft or satellite imagery.

If you have a project which you'd like the Remote Sensing Program to consider, contact John A. Stanturf, Research Associate, Remote Sensing Program, School of Civil and Environmental Engineering, Hollister Hall, Cornell University, Ithaca, New York 14853, phone: (607) 256-4330 or 256-5074.

DFN:nd

*Ed. This was mailed to
all planning and environ-
mental agencies. The*

County
Director
(518) 765-3635Agriculture/
Home Horticulture
765-2331Home
Economics
765-28744-H Youth
Development
765-2327Community Resources
Development
765-3635

September 29, 1980

John A. Stanturf
Remote Sensing Program
School of Civil and Environmental Engineering
Hollister Hall
Ithaca, NY 14853

Dear John:

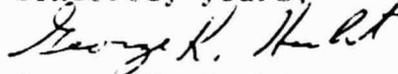
Thanks for your letter and your interest in our alternate energy ideas, an interest which I gather is shared by very few of your Cornell colleagues. As you may recall, most of the effort of the Cornell faculty with whom we discussed this project was spent trying to discourage it.

Nevertheless, we have proceeded and have grant proposals pending at both N.Y.S. E.R.D.A. and the U.S. Dept. of Energy. These proposals are to test the ideas of on-land application of sewage sludge as a soil conditioner and the use of hybrid poplars as a bio-mass crop. To work up these proposals the City used as consultants two local engineering firms, a professor from N.Y.U. (on the alcohol production aspect), Ray Marler from the Syracuse School of Forestry (on poplars), and Lew Naylor from Cornell (on sludge). Lew is familiar with the project and plans to be quite involved if it is funded. I would suggest you visit with him. I'm sure you can add a lot to the proposed project.

A possible good use for the remote sensing capability might be to identify those areas of marginal farm land in the region which might be most suitable for bio-mass farming. I'm sure Larry Smith, Albany County Planning Director, would also like to talk to you about remote sensing possibilities. Tell him I suggested that you make contact with him.

Thank you again for your interest in this project.

Sincerely yours,



George K. Hecht
Cooperative Extension Agent
Community Resources Development

GKH:ek

Albany County Planning Board



STEDMAN HOUSE
1 LODGE STREET
ALBANY, N.Y. 12207
(518) 445-7964

October 1, 1980

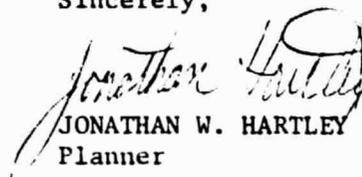
Cornell University
Remote Sensing Program
School of Civil and Environmental Engineering
Hollister Hall
Ithaca, NY 14853

Dear Sirs:

I noticed in your September 1980 information letter to the Cooperative Extension Associations that you have experimented with remote sensing for identification of windmill sites. Our office has been working with one of the County's municipalities in exploring wind potential for electrical generation. We are considering expanding this to a County wide study in order to identify areas in Albany County with the greatest potential. Therefore, could you please send me any information you have on the application of remote sensing for such a purpose. I am particularly interested in the methodology, equipment needs, and imagery criteria. In addition, if you are aware of other references that may be of assistance in this effort please let me know.

I look forward to your response.

Sincerely,


JONATHAN W. HARTLEY
Planner

JWH/sa



NORTHERN TIMBERLANDS DIVISION
Deferiet, N.Y. 13628 315/493-3540

October 13, 1980

Mr. John A. Stanturf
Research Associate
Remote Sensing Program
Hollister Hall
Ithaca, New York 14853

Dear Mr. Stanturf:

I would be very interested in taking advantage of your offer to participate in the remote sensing program. There are several problems which I have encountered over the past year and I am certain that a project such as this could help to solve them.

I have listed some of these problems below:

1. Softwood types (acres and species) within a 100 mile radius of our mill in Deferiet.
2. Topographical survey of our lands
 - a. Areas too steep to log with mechanical equipment.
 - b. Areas too steep to log with conventional crews.
3. Soil composition, depth, drainage.
 - a. For timber stand improvement site location.
 - b. For possible gravel deposits.

I would like to meet with you sometime to discuss these topics. I am usually in the office on Mondays. Feel free to call me and we'll set up a date and a place. Attached is my business card.

Sincerely,

A handwritten signature in cursive script, appearing to read 'James K. Waters'.

James K. Waters
Forestry Manager
New York District
NORTHERN TIMBERLANDS DIVISION

JKW:sfi
Enc.
cc: Mr. P. C. Nowell
Mr. H. D. Phillips



STEDMAN HOUSE
1 LODGE STREET
ALBANY, N.Y. 12207
(518) 445-7964

October 22, 1980

Mr. Warren R. Philipson
Cornell University
Remote Sensing Program
School of Civil and Environmental Engineering
Hollister Hall
Ithica, NY 14853

Dear Mr. Philipson:

Upon returning from vacation Larry Smith and I discussed your phone conversation of October 5th. I have searched our files for a letter transmitting our final comments to you, but can only find our mailing list and the local comments which we received. I'm not sure why this information wasn't forwarded to you at the time, but sincerely apologize for the oversight and lack of consideration. I just hope that no irreparable damage has been done to future interaction between our offices.

To recap what should have been said, after we received your report "Landslide and Erosion Susceptibility within the Normans Kill Drainage Basin, Albany County, New York", we sent copies to county agencies involved in land use related activities as well as local planning and/or building departments. Enclosed is a complete list of those agencies which received and reviewed your final report.

The general responses of these agencies, including the enclosed written comments, were quite favorable as to the overall quality of the material. The most common comment was a reluctance to depend entirely on the information. This however was a limitation clearly cited in the final report. Another comment often made was the lack of currentness of the data. At the time of the study, a 1977 black and white photo series of the study area was available through Lockwood Mapping Inc. of Rochester. This flight has not been widely publicized since it was produced for the County Tax Mapping Program. I'm surprised Kevin Millington from our office didn't mention it in any correspondence prior to the study. Despite this, however, the overall area, with a few exceptions has changed very little since 1973.

As to the expected use of the study, despite little activity in the Normans Kill Basin to date, we expect the study's primary use to be as an "alarm" to potential problems when a building project is proposed. Once identified, further study can be required prior to final approval of the project. This "alarm" function has become particularly relevant with the environmental assessments required by the State Environmental Quality Review Act. This type of assessment however is the responsibility of the local municipality with little or no input from our office. Therefore the full utility of your study

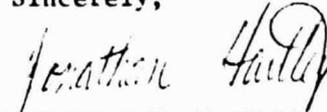
Page 2

for project reviews remains to be tested. Beyond this, your study should serve as support data for various short and long term plans in the county. Foremost of these would be a Normans Kill Linear Park. This is of particular interest to Mayor Corning of the City of Albany, although only in the conceptual stages at this point.

Since our use of aerial photographic interpretation for a land use inventory in 1977, we as a staff have been particularly interested in the general and specific application of remote sensing to planning and land use related problems. I hope we can continue an open and active communication link despite our earlier mix up.

If you have any questions as to the distribution or use of your study or any other questions feel free to contact us. Once again, we are very appreciative of the assistance you have provided and hope that it continues in the future.

Sincerely,


JONATHAN W. HARTLEY
Planner

JWH/as
Encl.

County of Fulton

COUNTY BUILDING
JOHNSTOWN, NEW YORK 12095

Telephone (518) 762-4832

PLANNING DEPARTMENT

PAUL J. O'CONNOR, Director

October 22, 1980

Dr. Warren Philipson
Remote Sensing Program
Hollister Hall
Cornell University
Ithaca, NY 14853

Dear Warren,

RE: USE OF REMOTE SENSING INFORMATION IN THE TOWN OF MAYFIELD PLANNING PROGRAM

Remote sensing, to the extent of sand and gravel resources, was used by the Town of Mayfield Planning Board in developing the Town's Land Development Code (included zoning provisions). The information provided included both a written report and a map, at a scale of 1:24,000.

The information received was valuable in three ways:

1. It provided mapped location of existing mining operations;
2. The extent of primary locations of sand and gravel deposition was mapped;
3. The written report provided a limited assessment concerning the depth and extent of the deposits.

The quality of deposition materials was not identified in the report, since this can only be determined by field inspection. However, it was assumed that most deposits would be of a high quality, considering the present quality of material.

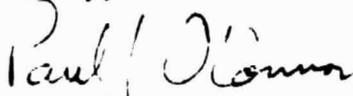
Though general in nature, the information was presented to the Town Planning Board at regular meetings held in July, 1979, and March and May, 1980. The finalized Land Development Code did not directly refer to the information received, but it was clearly reflected in the schedules of uses and in considering those districts where sand and gravel mining operations would be allowed.

DR. WARREN PHILIPSON
October 22, 1980
Page 2

A copy of the proposed development map is enclosed for your records.

Again, thank you for the excellent services your department has provided to the Fulton County Planning Department. If we can assist you, in some way, please let me know.

Sincerely,



Paul J. O'Connor
Planning Director

PJO:sjk
Enclosure



**NEW YORK
STATE ENERGY OFFICE**

ROCKEFELLER PLAZA
ALBANY, NEW YORK 12223
JAMES L. LAROCCA, COMMISSIONER

December 9, 1980

Dr. Warren Philipson
Remote Sensing Program
Hollister Hall
Cornell University
Ithaca, New York 14853

Dear Warren:

I am writing to thank you and Dave Smith for the work you did to identify sites for wind resource monitoring in the Energy Office's Wind Feasibility program. The materials for Erie County arrived recently, and I have forwarded a copy of the maps to the County Energy Office to aid them in selecting sites under the program. I have already done this with materials for Niagara and Orleans Counties.

I will keep you informed of the results of the monitoring as the program proceeds, so that you can compare our data with your predictions.

Again, thanks, and best wishes for the holidays.

Sincerely,

Paul F. Wendelgass
Bureau of Resource Development

PFW/lal
cc: Dave Smith

APPENDIX G

Recent Newsletters

The Newsletter, a monthly report of articles and events in remote sensing, is sent to members of the Cornell community who have an interest in sensors and their applications.

THE NINTH YEAR

The Remote Sensing Program, begun in 1972, is supported by a grant from NASA, the National Aeronautics and Space Administration, to the School of Civil and Environmental Engineering, Cornell University. The activities of the Program Staff are of three kinds: instructing students and performing research in remote sensing, building upon thirty years experience in aerial photographic studies; strengthening communication among persons interested or active in remote sensing; and soliciting and conducting user-oriented applied research projects. These projects must involve unique benefit- or action-producing applications of aircraft or satellite remote sensing in New York or the Northeast. These projects are generally conducted at no charge to the user.

NASA-sponsored projects completed during the summer include: an inventory of abandoned wells in the Allegheny State Park; the development of a methodology for extending snow records with Landsat data; and an assessment of timber resources for a wood power plant. Continuing projects are focusing on: site selection for wind mills; coniferous forest inventory for a particle board manufacturing plant feasibility study; plant spectral response to sulphur dioxide; relationships among vineyard spectral characteristics, yield and other management factors; landfill leachate; and river flooding. The latter two topics are funded in part by the N.Y.S. Department of Health and the Office of Water Research and Technology (OWRT), U.S.D.I., respectively. Tentative approval has also been received for an OWRT-funded project on lake water quality. This 12-month study would begin in October and be conducted cooperatively with Cornell's Department of Natural Resources. (Continued, p.2).

ASP CALL FOR PAPERS

The 47th Annual Meeting of the American Society of Photogrammetry will be held in Washington, D.C., 22-27 February 1981. Proposals for papers in many areas of remote sensing will be accepted, including sensor systems, image data processing, and applications. Proposals should be submitted no later than September 2, 1980 to A.T. Cokenias, ASP Technical Program Committee, US Geological Survey, 524 National Center, Reston, Va. 22092 (tel. 703-860-6301). Proposals must include a title, author's name, address and telephone number, professional affiliation and position, and an abstract of less than 200 words. Presentation time will be limited to 20 minutes.

LANDSAT UPDATE

Landsat-3 is once again the primary spacecraft over the U.S. Launched in 1978 with a one-year design life, it was retired in late 1979 after attitude control problems developed. Problems with the quality of the multispectral scanner (MSS) data from Landsat-3 due to a late line start caused NASA to switch back to the older spacecraft. Routine sensing over the U.S. has been done by Landsat-2 since June 6th. Landsat-3 is used only over foreign areas and by special request over the U.S. The current plan is to launch a craft by 1982 with an MSS and tape recorder in order to provide continuous Landsat coverage. This Landsat-? may or may not have a return beam vidicon. Landsat-D, with a thematic mapper, is still planned.

SEMINAR IN REMOTE SENSING

The Seminar in Remote Sensing will not be held during the Fall Semester 1980, but will be offered again during the Spring of 1981.

2 Cornell's Remote Sensing Program (cont'd)

The staff of the Remote Sensing Program includes Ta Liang, principal investigator, Warren R. Philipson, co-investigator, John A. Stanturf, research associate, Thomas L. Erb, research specialist, Chain-Chin Yen, data analyst, and Pat Webster, secretary. Donald J. Belcher, Arthur J. McNair, and Ernest Hardy are general consultants to the program. Assistance has been provided by many Cornell and non-Cornell personnel for specific projects. Individuals who have contributed over the summer include Dr. Michael J. Duggin, of the SUNY College of Environmental Sciences and Forestry, Syracuse, N.Y. and Cornell students Lisa K. Balliett, William R. Hafker, Karen L. Jahn, Katsutoshi Kozai, Sandra J. Matulonis, Katherine A. Minden, David S. Smith, and William L. Teng.

NATIONAL HIGH ALTITUDE PHOTOGRAPHY UPDATE

An updated progress report for the National High Altitude Photography effort (described in the Dec. 1979 Newsletter) can be obtained by writing Paul A. Antill, US Geological Survey, National Center MS 512, Reston, Va. 22092 (tel.: 703-860-6212). Both black and white and color infrared photos can be ordered from the EROS Data Center, Sioux Falls, South Dakota 57198 by including the geographic coordinates of the area needed. Only color IR is available from the ASCS Aerial Photo Field Office, PO Box 30010, Salt Lake City, Utah 84130.

CONFERENCES/SHORT COURSES

Thermal Infrared Sensing Applied to Energy Conservation In Building Envelopes (Thermosense III); 2-5 Sept.; in Minneapolis, Minn. Contact: SPIE, P.O. Box 10, Bellingham, Washington 98225 (tel. 206-676-3290).

IEEE Computer Society 9th Workshop On Applied Imagery Pattern Recognition; 22-23 Sept.; at University of Maryland, College Park, Md. Theme: High Speed Image Processing For Practical Applications. Contact: AIPR Program Committee, 4405 Echo Court, Woodbridge, Va. 22193.

Fall Technical Meetings, Amer. Soc. Photogrammetry-Amer. Congress Surveying and Mapping; 7-10 Oct.; in Niagara Falls, NY. Contact: David J. Millard, 47 Campus Dr., West Seneca, NY 14224 (tel. 716-675-0900).

Remote Sensing For Resource Management; 28-30 Oct.; in Kansas City, Mo. Contact: Soil Conservation Society Amer., 7515 Northeast Ankeny Road, Ankeny, Iowa 50021 (tel. 515-289-2331).

SELECTED ARTICLES AND PUBLICATIONS

McGinnis, D.F., R.A. Scofield, S.R. Schneider, and C.P. Berg. 1980.

Satellites as aid to water resource managers. Journ. Water Resources Planning and Manage., ASCE.

McNolty, F. and R. Clow. 1980. Methodology for target discrimination. Applied Optics 19:6:984-999.

Photogram. Eng'g. and Remote Sensing 1980. v. 46, n.3 (March):

-Welch, R. Measurements from linear array camera images.

-Renner et al. A photogrammetric contouring method for radiation therapy.

-Ghosh, S.L. Photogrammetry for police use: Experience from Japan

-Lo and Chan. Rural population estimation from aerial photographs.

-Ackerson and Fish. An evaluation of landscape units.

-Henderson, F.M. Effects of interpretation techniques on land-use mapping accuracy.

-Badhwar, G.D. Crop emergence data determination from spectral data.

The Newsletter is made possible by a grant from the NASA Office of University Affairs. Comments or correspondence should be directed to John A. Stanturf, Remote Sensing Program, Cornell University, 464 Hollister Hall, Ithaca, New York 14853 (tel.: 607-256-4330).

The Newsletter, a monthly report of articles and events in remote sensing, is sent to members of the Cornell community who have an interest in sensors and their applications.

MONITORING HARDWOOD FOREST CLEARCUTTING

The value of small scale remotely sensed data for monitoring clearcuts was assessed by William Hafker in a recently completed thesis for a Master of Science degree at Cornell University. Hafker examined clearcutting in predominantly hardwood forests, using high altitude aircraft and satellite data. Manual photo-interpretation techniques were used to analyze images acquired by high altitude aircraft, Skylab Multi-spectral and Earth Terrain cameras (ETC), Landsat Multispectral Scanner (MSS), and the Landsat-3 Return Beam Vidicon. Landsat MSS imagery was also analyzed using a color-additive viewer and by digital image analysis. The value of each type of remotely sensed data was judged by the ease and accuracy of clearcut identification, and by the amount of detail discernible, especially regarding revegetation.

Results of a comprehensive study of sites in the Allegheny National Forest in Pennsylvania indicated that high altitude aerial photography, especially color infrared photography acquired during the growing season, was well suited for identifying clearcuts and assessing the extent of revegetation. Although photographs acquired with Skylab's ETC also yielded good results, only incomplete inventories of clearcuts could be made using Landsat imagery. Results of a less comprehensive study in New York's Adirondack Park were similar to those in Pennsylvania, but even less satisfactory results were obtained with Landsat imagery. Several factors could have contributed to the increased difficulty of clearcut detection in the Adirondack Park, chief among these being greater topographic relief and associated illumination variations, differences in harvesting practices including amount of timber felled and removed, amount of soil disturbance, distribution of slash, the amount of vegetation present after harvest, and the presence of coniferous and mixed vegetation types. (Continued, p.2).

ASP CALL FOR PAPERS

A special session on Engineering and Site Selection in Fragile Environments will be held during the American Society of Photogrammetry Annual Meeting on February 24, 1981 in Washington, D.C. The session will be sponsored by the Engineering Applications Committee of ASP's Remote Sensing Applications Division. Abstracts of 200 words, with author's name, address and telephone number should be sent to: Dr. Robert A. Ryerson, Canada Centre for Remote Sensing, Energy Mines and Resources, Ottawa, Canada K1A 0Y7 (tel. 613-995-1210). The ASP deadline of September 2 is extended for this session only to October 10. Emphasis will be on practical solutions using remote sensing.

CALL FOR PAPERS

The Fifteenth International Symposium on Remote Sensing of the Environment will be held in Ann Arbor, Michigan, 11-15 May 1981. Contributed papers will be presented in multidisciplinary poster sessions. The deadline for submitting a summary of a proposed presentation is 1 November 1980. Summaries must be between 300 and 1000 words long, contain no figures or references, and 20 copies in English must be sent to Dr. Jerald J. Cook, Environmental Research Institute of Michigan, P.O. Box 8618, Ann Arbor, Mich. 48107 (tel. 313-994-1200). Each summary should contain a justification for the work, an explanation of its relationship to the state-of-the-art, details of results to date, and in the case of a new or innovative approach, a discussion of how it differs from existing methods.

2 Monitoring Hardwood Clearcutting (continued)

The results of this study and the methods suggested for clearcut monitoring would be best suited to regions of hardwood forests where nearly all trees are removed in a single cutting and where the topography is not excessively mountainous.

The study was directed by Ta Liang and Warren R. Philipson, and supported by NASA Grant NGL 33-010-171. For further information, contact Dr. Philipson, Cornell University, Hollister Hall, Ithaca, N.Y. 14853 (tel. 607-256-4330).

CONFERENCES/SHORT COURSES

Cartographic Information Society organizational meeting, 2-4 Oct; in Milwaukee, Wisconsin. Contact: CIS c/o Christine Reinhard, 143 Science Hall, Madison, Wisconsin 53706. CIS is a new professional organization aimed at promoting communication, coordination and cooperation among the producers, disseminators, and users of cartographic information.

Synthetic Aperture Radar with Remote Sensing Applications; 14-17 Oct; \$580; contact: Continuing Engineering Education Program, George Washington Univ., Washington, D.C. 20052 (tel. 202-676-6106; 800-424-9773; telex 64374).

PUBLICATIONS AVAILABLE

Proc. 46th Annual Mtng., American Soc. Photogrammetry. 528 pp. Held St. Louis, March 1980. Avail: Amer. Soc. Photogrammetry, 105 Virginia Ave., Falls Church, Va. 22046. \$7.50 members, \$12.50 non-members. Include \$1.00 per publication for postage and handling.

Remote Sensing and Resources Management, Ferdinand Bonn, editor. A collection of papers given at the congresses of The Quebec Remote Sensing Association. Papers are in English or French, with abstracts in the other language. Avail: Teledetection et gestion des ressources a/s Departement de Geographie, Universite de Sherbrooke, Sherbrooke, Quebec, Canada J1K 2R1. \$20 members A.Q.T., \$28 non-members.

New York State Atlas. A new edition, containing 39 multicolor maps and a populated place name index, is available from the Map Information Unit., NYS Dept. Transportation, State Campus, Albany, N.Y. 12232. Cost: \$15. Individual atlas pages are 75 cents each; forms for ordering are available from the Map Information Unit.

SELECTED ARTICLES AND PUBLICATIONS

Buchanan, M.D. and R. Pendergrass. 1980. Digital image processing: Can intensity, hue and saturation replace red, green, and blue? Electro-Optical System Design 12:3:29-36.

MacDonald, R.B. and F.G. Hall. 1980. Global crop forecasting. Science 208:670-679.

Aldrich, R.C. 1979. Remote sensing of wildland resources: A state-of-the-art review. USDA Forest Service Gen. Tech. Rep. RM-71. Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado.

Stonetz, et al., 1980. Extension of laboratory-measured soil spectra to field conditions. Soil Science Soc. Amer. Jour., 44:572-574.

Eogucki, D.J., G.K. Gruending, and M. Madden. 1980. Remote sensing to monitor water chestnut growth in Lake Champlain. Jour. Soil Water Conserv. 35:79-81.

Kiefer, R.W. ed. 1980. Civil engineering applications of remote sensing. Proc. Specialty Conf., ASCE Aerospace Div., Madison, Wisconsin Aug. 13-19, 1980. Amer. Soc. Civil Engineers.

The Newsletter is made possible by a grant from the NASA Office of University Affairs. Comments or correspondence should be directed to John A. Stanturf, Remote Sensing Program, Cornell University, 464 Hollister Hall, Ithaca, New York 14853 (tel.: 607-256-4330).

The Newsletter, a monthly report of articles and events in remote sensing, is sent to members of the Cornell community who have an interest in sensors and their applications.

RESOURCE INFORMATION LABORATORY -- UPDATE

The Resource Information Laboratory (RIL), a unit of Cooperative Extension in Cornell's College of Agriculture and Life Sciences, supports land use and resource management programs in New York State. RIL maintains and continually supplements an airphoto library that contains photographs of every county in New York, providing sequential coverage in many areas for 20 years or more.

A contract recently was signed with the U.S. Agency for International Development for RIL staff to develop land use/land cover maps for the Yemen Arab Republic. An integral part of the project, coordinated by Ronald Senykoff with James Skaley, will be training Yemeni nationals at Cornell in techniques for satellite imagery enhancement, interpretation and mapping.

RIL continues to offer in-depth training in land use classification, natural resource inventories, geographic referencing, and airphoto interpretation of land use. Recent publications are "From Landforms to Avian Habitat--A Look at Topology," by J.E. Skaley, and "An Application of Sequential Air Photo Analysis to the Identification and Mapping of Closed Landfill Sites," by E.M. Barnaba. For further information, contact Ernest E. Hardy, Director, or Eugenia M. Barnaba, Manager of Technical Services, at RIL, Box 22, Roberts Hall, Cornell University, Ithaca, N.Y. (tel. 607-256-6520). RIL is located near the Tompkins County Airport.

ARCHIVE OF ENVIRONMENT SATELLITE DATA

The Satellite Data Services Division of the National Oceanic and Atmospheric Administration's (NOAA) Environmental Data and Information Service (EDIS) maintains the Archive of all environmental meteorological and oceanographic satellite data from the NOAA satellites and from some NASA experimental satellites for regions around the world. Satellite data and derived products are available in photographic format, digital tapes, and paper copy. The Archive consists of several million photographic negatives and digital tapes from TIROS-1 (April 1960) through the present TIROS-N/NOAA-6 series of polar-orbiting satellites, from the SMS/GOES Geostationary Satellites (May 1969 through the present), and from such non-operational satellites as GEOS-3, SEASAT, and NIMBUS-7.

The SDSD publishes the "Satellite Data Users Bulletin" which contains information on new acquisitions and certain satellite data. Anyone desiring to be added to the distribution list for the Bulletin or desiring specific information on data holdings, availability, or price is requested to contact: Satellite Data Services Division (SDSD), NOAA/EDIS/NCC, Room 100, World Weather Building, Washington, D.C. 20235 (tel. 301-763-8111 commercial, 763-8111 FTS).

CONFERENCES/SHORT COURSES

Workshop on Remote Sensing and Geographic Information Systems in the Planning Environment, at the Univ. California at Berkeley; 17-21 Nov; Contact: Remote Sensing, University of California Extension, 2223 Fulton St., Berkeley, Ca. 94720 (tel. 415-642-1061).

Colloquium on the Application of Data from the Next Generation of Earth Resources Satellites, in Montreal, Quebec; 25-26 Nov.; Contact: Keith P.B. Thomson, Canada Centre for Remote Sensing, 2464 Sheffield Road, Ottawa, Canada K1A 0Y7 (Tel. 613-995-1210).

Terrain Analysis; 17-21 Nov.: \$655; Contact: Continuing Engineering Education Program, George Washington Univ., Washington, D.C. 20052; (tel. 202-676-6106 or 800-424-9773; telex 64374).

ORIGINAL PAGE IS
OF POOR QUALITY

The new International Journal of Remote Sensing has begun publication (see Selected Articles, this issue). It is the official journal of the Remote Sensing Society, a UK-based organization. Subscriptions are \$80 annually (US, Canada, and Mexico); members of the RSS are entitled to a 50% discount. To subscribe, contact Taylor and Francis, Ltd., Rankine Road Basingstoke, Hampshire UK RG24 OPR.

SELECTED ARTICLES

- Hovis, et al. 1980. Nimbus-7. Coastal Zone Color Scanner: System description and initial imagery. Science vol. 210:60-63.
- Gordon et al. 1980. Phytoplankton pigments from the Nimbus-7 Coastal Zone Color Scanner: Comparisons with surface measurements. Science vol. 210:63-66.
- Murray, E.R., D.D. Powell & J.E. van der Laan. 1980. Measurement of average atmospheric temperature using a CO₂ laser radar. Applied Optics. 19:11:1794-1797.
- International Journ. Remote Sensing 1980. v.1, no.1
- Berg and de Paratesi. Some significant results of a remote sensing experiment under European conditions (AGRESTE project).
 - Klemas. Remote sensing of coastal fronts and their effects on oil dispersion.
 - Raney. SAR processing of partially coherent phenomena.
 - Plevin and Honvault. The ESA remote sensing programme.
 - Tucker et al. Relationship of crop radiance to alfalfa agronomic values.
 - Curran. Relative reflectance data from preprocessed multispectral photography.
 - Schneider. Interpretation of satellite imagery for determination of land use data.
- Remote Sensing of Environment 1980. vol. 9, no.3
- Murphee and Anger. An empirical method for determining albedo contribution to satellite photometer data.
 - Gordon. Utilizing Landsat imagery to monitor land use change: A case study in Ohio.
 - Johnson. Remote sensing and spectral analysis of plumes from ocean dumping in the New York Bight apex.
 - Ketchum and Lohanick. Passive microwave imagery of sea ice at 33 GHz.
 - Parikh and Ball. Analysis of cloud type and cloud amount during GATE from SMS infrared data.
 - Holmes et al. Optimum thermal bands for mapping general rock type and temperature from space.
 - Weaver and Green. Simulation study of geometric shape factor approach to estimating earth emitted flux densities from wide field-of-view radiation measurements.
- Remote Sensing of Environment 1980. v.9, n.4
- Hlavka et al. The discrimination of winter wheat using a growth-state signature.
 - Byrne & Davis. Thermal inertia, thermal admittance, and the effects of layers.
 - Dave, J.V. Simulation colorimetry of the earth-atmosphere system.
 - Pratt, D.A. Two-dimensional model variability in thermal inertia surveys.
 - Legeckis et al. Comparison of polar and geostationary satellite infrared observations of sea surface temperatures in the Gulf of Maine.
 - Jobson et al. Remote sensing of benthic microalgal biomass with a tower-mounted multispectral scanner.

The Newsletter is made possible by a grant from the National Aeronautics and Space Administration to Cornell's School of Civil and Environmental Engineering. Address comments to John A. Stanturf, Cornell University, Hollister Hall, Ithaca, N.Y. 14853 (tel. 607-256-4330).

The Newsletter, a monthly report of articles and events in remote sensing, is sent to members of the Cornell community who have an interest in sensors and their applications.

ESTIMATING FUELWOOD POTENTIAL USING REMOTE SENSING

Uncertainty in petroleum cost and supply has sparked interest in alternative energy sources, including wood. Under-utilized forest resources in Northeastern states such as New York, where annual growth significantly exceeds annual harvest, could supply fuelwood for generating electricity. The New York State Energy Office requested the Cornell Remote Sensing Program to assess the feasibility of operating a ten megawatt wood-fired power plant in the Adirondack region. The primary concern was the availability of sufficient woody material within economic hauling distance.

In general, information on forest resources was too aggregated to provide a detailed enough estimate of fuelwood supplies. As such, the Cornell staff used high altitude, color infrared aerial photographs and Landsat to estimate the amount of potentially available fuelwood within 30 km of a proposed site. The first step was to delineate available forest land area by excluding non-forested land, wetlands, water bodies, land with slopes exceeding 15%, and land in public ownership. Large blocks of land owned by the forest industry were noted as well, but considered potentially available for fuelwood harvest.

The second step was to stratify the forest land into three cover classes --deciduous, coniferous, and mixed--in order to apply available growth and inventory data. This was accomplished using the aerial photographs; interpretation of coniferous trees was checked using winter scene Landsat imagery.

Thirty-seven percent of the land, totaling 1056 km² was forested and potentially available. Of this, 51% was composed of mixed, 39% deciduous, and 10% coniferous stands. Fuelwood potentially available was estimated conservatively--assuming only cull material and mortality--at 79,750 green tons per year, just short of the 86,640 tons necessary to supply the plant. Less conservative estimates were that 1.35, 27, or 75 times the needed fuelwood could be supplied. (continued p.2)

CALLS FOR PAPERS

The Ninth Remote Sensing of Earth Resources Conference will be held at the Univ. of Tennessee Space Institute, Tullahoma, Tenn., 24-26 March 1981. Proposals for papers should be submitted to: Dr. F. Shahrokhi, Conference Director, Univ. Tenn. Space Inst., Tullahoma, Tenn. 37388. Proposals should include a title, author's name, address, and position, and an abstract of approximately 150 words.

Workshop on Inplace Inventories, to be held at the Univ. of Maine, Orono, Me., 9-14 Aug. 1981. Abstracts of "how-to" papers dealing with natural resource classification, mapping, sampling designs, or information management should be sent to: H. Gyde Lund, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, 240 West Prospect St., Ft. Collins, Colo. 80526 (Tel. 303-221-4390, ext. 202).

Late Call--Conference on Remote Sensing Education, to be held at LARS, Purdue Univ., West Lafayette, Ind., 17-20 May 1981. Abstracts should be sent by 1 Dec. 1981 to: Ms. Shirley M. Davis, LARS, 1220 West Potter Drive, West Lafayette, Ind. 47906.

PUBLICATION AVAILABLE

The complete Index to Photogrammetric Engineering and Remote Sensing Volumes I-XLV (1934-1979). Cost: \$7.50 to ASP Members, \$15 otherwise, plus \$1 postage and handling. Contact: Amer. Soc Photogrammetry 105 North Virginia Ave., Falls Church, Va. 22046.

2 Estimating Fuelwood Potential (cont'd)

The study was conducted by John Stanturf, Warren Philipson, Lisa Balliett, and Karen Jahn, and supported by NASA Grant NGL 33-010-171. For further information, contact John Stanturf, Cornell University, 464 Hollister Hall, Ithaca, New York 14853 (tel. 607-256-4330).

SELECTED ARTICLES

Photogrammetria. 1980. v.35, n.5.

-Debrock and Verduyn. Densitometric analysis of colour aerial photographs - a new approach.

Applied Optics. 1980. v.19, n.13.

-Doda & Green. Surface reflectance measurements in the UV from an airborne platform. Part 1.

-Barnes & Price. Calibration of a satellite IR radiometer.

-Kimes et al. Complexities of nadir-looking radiometric temperature measurements of plant canopies.

Applied Optics. 1980. v.19, n.14.

-Kahle et al. Middle IR multispectral aircraft scanner data: Analysis for geological applications.

-Randhawa & van der Laan. Lidar observations during dusty IR Test-1.

Applied Optics. 1980. v.19, n.15.

-Bukata et al. Nonzero subsurface irradiance reflectance at 670nm from Lake Ontario water masses.

Applied Optics. 1980. v.19, n.16.

-Sydor, M. Remote sensing of particulate concentrations in water.

-Kimes & Smith. Simulation of solar radiation absorption in vegetation canopies.

ITC Journal. 1979. v.2

-Hilwig. Selection of Landsat MSS data for inventories of earth resources.

-Banyard. Radar interpretation based on photo-truth keys.

-Versteegh. The effect of plot size and plot spacing on the precision of line plot sampling in a tropical rain forest.

-Kemper. Examples of air photo-interpretation in soil surveys for an agricultural land development project in North East Brazil.

Canadian Journal Remote Sensing. 1980. v.6, n.1.

-Zwick et al. A four-channel photometer for reflectance profile measurements in airborne remote sensing.

-Brisco & Protz. Corn field identification accuracy using airborne radar imagery.

-Brown & Ahern. The field spectral measurements program of the Canada Centre for Remote Sensing.

-Singhroy & Wightman. The training of remote sensing technicians in Canada.

Remote Sensing of Environment. 1980. v.10, n.1.

-Finley & Baumgardner. Interpretation of surface-water circulation, Arkansas Pass, Texas, using Landsat imagery.

-Tucker, C.J. Remote sensing of leaf water content in the near infrared.

-Berlin et al. Possible fault detection in Cottonball Basin, California: An application of radar remote sensing.

-Estes et al. Impacts of remote sensing on U.S. geography.

-McConaghy, D.C. Geographic location of individual pixels.

Kumar, R. 1980. Separability of agricultural cover types in spectral channels and wavelength regions. IEEE Transac. on Geoscience & Remote Sensing. GE-18:3:263-267.

This Newsletter is made possible by a grant from the National Aeronautics and Space Administration to Cornell's School of Civil and Environmental Engineering. Address comments to John A. Stanturf, Cornell University, Hollister Hall, Ithaca, N.Y. 14853. (tel. 607-256-4330).

APPENDIX H

Newsletter Recipients

CORNELL REMOTE SENSING NEWSLETTER
LIST OF RECIPIE

CAMPUS GROUPS AND INDIVIDUALS*

1. Administration
F.H.T. Rhodes (President, Cornell)
W.K. Kennedy (Provost, Cornell)
J.N. Spencer (Vice Provost)
E.L. Ziegler (Asst. to Vice Provost)
2. Administrative Programming Service
C. Selvarajah
3. Aerospace Studies (Air Force R.O.T.C.)
4. Agricultural Economics
O.D. Forker (Chairman; Prof.)
D.J. Allee (Prof.)
H.E. Conklan (Prof.)
K.V. Gardner (Sr. Extension Assoc.)
W.C. Hunt (Extension Assoc.)
5. Agricultural Engineering
L.H. Irwin (Assoc. Prof.)
G. Levine (Prof.; Dir. Center for Envir. Research)
M.F. Walter (Asst. Prof.)
6. Agronomy
R.F. Lucey (Chairman; Prof.)
W.F. Cronney (Sr. Ext. Assoc.)
M. Drosdoff (Prof. Emer.)
G.W. Olson (Assoc. Prof.)
J.H. Peverly (Assoc. Prof.)
A.R. Van Wambeke (Prof.)
7. Anthropology
8. Applied and Engineering Physics
A.F. Kuckens (Prof.)
9. Astronomy
F.D. Drake (Dir., Nat'l. Astronomy & Ionosphere Center; Prof.)

* Newsletters are sent to the main office of each department listed as well as to various individuals within the department. In addition, Newsletter are provided to graduate and undergraduate students, upon request.

9. Astronomy (Cont.)

- C. Sagan (Dir. Planetary Studies; Assoc. Dir. Radiophysics and Space Research; Prof.)
Y. Terzian (Chairman; Prof.)
J. Veverka (Assoc. Prof.)
10. Atmospheric Sciences (Agronomy)
B.E. Dethier (Prof.)
W.W. Knapp (Assoc. Prof.)
A.B. Pack (Sr. Extension Assoc.)
11. Biological Sciences
12. Boyce Thompson Institute
E.H. Buckley (Plant Biochemist)
J.S. Jacobson (Plant Physiologist)
13. City and Regional Planning
S. Saltzman (Chairman; Prof.)
B.G. Jones (Prof.)
14. Civil and Environmental Engineering
R.N. White (Dir.; School of C.E.E.; Prof., Structural Eng'g.)
G.B. Lyon (Asst. Dir.; Assoc. Prof., Envir. Eng'g.)
J.F. Abel (Assoc. Prof., Structural Eng'g.)
D.J. Belcher (Prof. Emer.)
J.J. Bisogni (Assoc. Prof., Envir. Eng'g.)
W.H. Brutsaert (Prof., Envir. Eng'g.)
R.I. Dick (Prof., Envir. Eng'g.)
L.B. Dworsky (Prof., Envir. Eng'g.)
T.L. Erb (Research Specialist, Remote Sensing Program)
G.P. Fisher (Prof., Envir. Eng'g.)
C.D. Gates (Prof., Envir. Eng'g.)
P. Gargely (Prof., Structural Eng'g.)
J.M. Gossett (Asst. Prof., Envir. Eng'g.)
S.C. Hollister (Prof. Emer.)
A.R. Ingraffea (Asst. Prof., Structural Eng'g.)
G.H. Jirka (Asst. Prof., Envir. Eng'g.)
P.R. Jutro (Sr. Research Assoc., Envir. Eng'g.)
F.H. Kulhawy (Assoc. Prof., Structural Eng'g.)
T. Liang (Prof., Remote Sensing Program)
J.A. Liggett (Prof., Envir. Eng'g.)
P. Liu (Assoc. Prof., Envir. Eng'g.)
D.P. Loucks (Chairman, Envir. Eng'g.; Prof.)
W.R. Lynn (Prof., Envir. Eng'g.)
W. McGuire (Prof., Structural Eng'g.)
A.J. McNair (Prof. Emer.)
A.H. Meyburg (Prof., Envir. Eng'g.)

14. Civil and Environmental Eng'g. (Cont.)
 A.H. Nilson (Chairman, Structural Eng'g.; Prof.)
 N. Orloff (Assoc. Prof., Envir. Eng'g.)
 T. Pekoz (Assoc. Prof., Structural Eng'g.)
 W.R. Philipson (Assoc. Prof., Remote Sensing Program)
 R.E. Schuler (Assoc. Prof., Envir. Eng'g. and Economics)
 C.A. Shoemaker (Assoc. Prof., Envir. Eng'g.)
 F.O. Slate (Prof., Structural Eng'g.)
 J.R. Stedinger (Asst. Prof., Envir. Eng'g.)
 G. Winter (Prof. Emer.)
 C.C. Yen (Data Analyst, Remote Sensing Program)
15. College of Agriculture and Life Sciences
 D.L. Call (Dean)
16. College of Architecture, Art and Planning
 K.C. Parsons (Dean; Prof.)
 H.W. Richardson (Chairman; Assoc. Prof.)
17. College of Engineering
 T.E. Everhart (Dean)
 P.R. McIsaac (Assoc. Dean; Prof., Electrical Eng'g.)
18. Computer Graphics
 D.P. Greenberg (Dir.; Prof., Arch.)
19. Computer Science
20. Design and Environmental Analysis
21. Ecology and Systematics
 J.F. Barlow (Assoc. Prof., Oceanography)
 G.E. Likens (Prof. Ecology)
 P.L. Marks (Assoc. Prof., Biology)
22. Education
23. Electrical Engineering
 R. Bolgiano, Jr. (Prof.)
 M. Kim (Prof.)
 W.H. Ku (Prof.)
 S. Linke (Prof.)
 C. Pottle (Assoc. Prof.)
 G.J. Wolga (Prof.)
24. Entomology
25. Entomology Extension
26. Floriculture and Ornamental Horticulture
 M.I. Adleman (Assoc. Prof., Landscape Architecture)
 A.S. Lieberman (Prof., Landscape Architecture)
 P.J. Troubridge (Asst. Prof., Landscape Architecture)
27. Geological Sciences
 J.E. Oliver (Chairman; Prof.)
 J.M. Bird (Prof.)
 A.L. Bloom (Prof.)
 A. Gibbs (Asst. Prof.)
 D.E. Karig (Assoc. Prof.)
 J. Ni (Research Specialist)
 W.B. Travers (Assoc. Prof.)
28. International Agriculture
 J.F. Metz (Director; Prof., Marketing)
 L.W. Zuidema (Asst. Director)
29. International Studies Center
30. Landscape Architecture Grad. Program
 L. Mirin (Asst. Prof.)
31. Materials Science and Engineering
32. Mechanical and Aerospace Engineering
33. Media Services
 S. Mosedale (Science Newswriter)
34. Military Science (Army R.O.T.C.)
35. Modern Languages and Linguistics
 E.J. Beukenkamp (Dir. Eng./Modern Language Program)
36. Natural Resources
 W.H. Everhart (Chairman; Prof.)
 M.B. Brunsted (Assoc. Prof.)
 J.W. Caslick (Senior Research Assoc.)
 L.S. Hamilton (Prof.)
 R.A. Malecki (Asst. Prof.)
 L. Mudrak (Extension Assoc.)
 R.T. Oglesby (Prof.)
 M.E. Richmond (Assoc. Prof.; Program Leader, Crop-Wildlife Research Unit)
 B.T. Wilkins (Assoc. Prof.; Program Leader, Sea Grant Advisory Service)
37. Naval Science (Navy R.O.T.C.)

38. N.Y.S. Agricultural Experiment Station, Ithaca
T. Muller
(Assoc. Director)
39. Operations Research and Industrial Engineering
T.J. Santner (Asst. Prov.)
A. Schultz (Prof.)
B.M. Turnbull (Assoc. Prof.)
40. Planning and Facilities
R.H. Clawson (Assoc. Dir. Energy Manag./Utilities)
41. Plant Pathology
S.V. Beer (Assoc. Prof.)
H.D. Thurston (Prof.)
42. Pomology
W.J. Kender (Chairman; Prof.)
43. Public Information
M.B. Stiles (Staff Writer)
44. Resource Information Laboratory
E.E. Hardy (Director)
E.M. Barnaba (Mgr. Technical Service)
45. Rural Sociology
H.R. Capener (Prof.)
46. Sociology
47. Sponsored Programs
T.R. Rogers (Director)
48. Theoretical and Applied Mechanics
49. Thermal Engineering
50. University Archives
G.P. Colman (Librarian)
51. U.S. Plant, Soil and Nutrition Laboratory
52. Vegetable Crops

OFF-CAMPUS GROUPS AND INDIVIDUALS

- Agency for Int'l. Development
Department of State
Washington, D.C.
(a) W.L. Eilers
(b) T.S. Gill
(c) C.K. Paul
(d) C. Withington
- Alberta Remote Sensing Center
Edmonton, Alberta, Canada
- Simon E. Ananaba
Department of Physics
Ahmadu Bello University
Zaria, Nigeria
- Prof. James M. Anderson
University of California
Dept. of Civil Engineering
Berkeley, California
- Dr. Richard W. Arnold
U.S. Dept. of Agriculture
Soil Conservation Service
Washington, D.C.
- Prof. John M. Arnon
Memphis State University
Dept. of Geology
Memphis, Tennessee
- Stan Aronoff
Dept. of Forestry
University of California
Berkeley, California
- Pat Ashburn
USDA/FAS
Houston, Texas
- Ing. Rafael J. Avila-F
Universidad del Zulia
Escuela de Geodesia
Maracaibo, Venezuela
- Mark Bagdon
New York State Energy Office
Albany, New York
- Lew Baker
Bendix Aerospace Systems
Division
Ann Arbor, Michigan
- Lawrence C. Baldwin
Centerville, Virginia
- James C. Barnes
Environmental Research &
Technology, Inc.
Concord, Massachusetts
- Dr. David J. Barr
Dept. Mining Petroleum Eng'g.
University of Missouri
Rolla, Missouri
- Dr. Alar S. Barrett
Optronics International
Chelmsford, Massachusetts
- Dr. A.R. Barringer
Barringer Research, Inc.
Golden, Colorado
- Robert Batchelder
University of Calgary
Calgary, Canada
- Thomas F. Baucom
Jacksonville State Univ
Department of Geography
Jacksonville, Alabama
- Frank Beatty
EROS Applications Assiat.
Facility
National Space Tech. Lab.
NSTL Station, Mississippi
- Gurdip S. Bedi
Embassy of India
Washington, D.C.
- Dr. Klass Jan Beek
Int'l. Inst. for Land
Recl. & Improvement
Wageningen, The Netherlands
- Jan P. Berger
Tams Engineers & Architects
New York, New York
- Ralph Bernstein
IBM Corporation
Gaithersburg, Maryland

ORIGINAL PAGE IS
OF POOR QUALITY

Dr. Joseph K. Berry
School of Forestry and
Environmental Studies
Yale University
New Haven, Connecticut

J.L. Bessis
Centre Spatial de Toulouse
Toulouse, France

Dr. Jose F. Betancourt
Dept. of Geography
SUNY College
Brookport, New York

Colin Betts
Oids College
Oids, Alberta, Canada

Martha A. Blake
Department of the Army
Construction Eng 3. Research
Laboratory
Champaign, Illinois

Mileva L. Blum
Minneapolis, Minnesota

Dr. Lloyd R. Breslau
U.S. Coast Guard
Research & Development Ctr.
Groton, Connecticut

James Brogan
Niagara Mohawk Power Corp.
Syracuse, New York

Robert Brower
Cayuga Co. Planning Dept.
Auburn, New York

Walley M. Brown
Bethesda, Maryland

Ned Buchman
Public Technology
Washington, D.C.

Dr. Peter Burbridge
Ford Foundation
Jakarta, Indonesia

Calspan Corporation
Buffalo, New York
(a) J.R. Schott
(b) J.E. Walker

Canada Centre for Remote
Sensing
Ottawa, Ontario, Canada
(a) R.J. Brown
(b) J. Cahlar
(c) E.A. Godby
(d) D.G. Goodenough
(e) B.D. McGurrian
(f) R.K. Roney
(g) W.M. Strome

The Canadian Aeronautics &
Space Institute
Ottawa, Ontario, Canada

Mr. Larry Carver
Map & Imagery Collections
Library
University of California
Santa Barbara, California

Alvaro F. Castro
U.N. Development Programme
Maputo, Mozambique

Central Intelligence Agency
Washington, D.C.
(a) J. Lynch
(b) F.P. Rossomondo

Sherry Chou Chen
Institut Pesquisas Espaciais
Sao Jose dos Campos, Brazil

Vern W. Cimmery
Bonneville Power Admin.
Portland, Oregon

Clark University
Graduate School of Geography
Worcester, Massachusetts

Jill Clayton
Geo. Abstracts, Ltd.
University of East Anglia
Norwich, England

Dr. Jerry C. Coliner
Dept. of Geology & Geog.
Hunter College
New York, N York

Dr. William Collins
School of Mines
Columbia University
New York, New York

James A. Dobbin
Toronto, Ontario, Canada

Rumberto G. dos Santos
SNLCS-EMBRAPA
Rio de Janeiro, Brazil

Art Dow
Gordon Head School
Victoria, BC, Canada

Dr. Wolfram U. Dreweas
Central Projects Staff
World Bank
Washington, D.C.

Eastman Kodak Company
Rochester, New York
(a) J.J. Graham
(b) C.P. McCabe
(c) M.R. Specht
(d) K.M. Vazy

East-West Center
Honolulu, Hawaii
(a) B. Currey
(b) B. Koppel

Ecol. Impact Surveil.
and Monitoring
Environ. Protection Serv.
Environment Canada
Ottawa, Ontario, Canada

Dr. A.J. Eggenberger
D'Appolonia Consulting
Engineers, Inc.
Pittsburgh, Pennsylvania

Jan K. Eklund
AGA Corporation
Secaucus, New Jersey

Curtis M. Elder
U.S. Bureau of Mines
Pittsburgh Mining & Safety
Research Center
Pittsburgh, Pennsylvania

Environmental Remote
Sensing Lab
Oregon State University
Corvallis, Oregon

ERIM
Ann Arbor, Michigan
(a) D.S. Lowe
(b) R.H. Rogers
(c) T.M. Wagner

Bernard J. Colner
U.S. Bureau of the Census
Washington, D.C.

Commonwealth Sci. & Indus.
Research Organization
Deniliquin, Australia

Merrill Conlitz
Regional Remote Sensing
Facility
Nairobi, Kenya

Dr. Robert J. Conner
CIBA-GEIGY Corp.
Greensboro, North Carolina

James Cordes
Cordes and Company
West Redding, Connecticut

Robert Crowder
N.Y.S. Commerce Dept.
Albany, New York

Dr. Peter H. Crown
Dept. of Soil Science
University of Alberta
Edmonton, Canada

Prof. LeRoy A. Daugherty
Dept. of Agronomy
New Mexico State University
Las Cruces, New Mexico

Dr. Donald W. Davis
Nicholls State University
Dept. of Earth Sciences
Thibodaux, Louisiana

Antonio Martinez de Aragon
Instituto Geografico Nacional
Madrid, Spain

Lic. Daniel R. de La Puente
Coordinador Area Informatica
I.I.R.R.
La Rioja, Argentina

Defense Mapping Agency
St. Louis, Missouri
(a) R.L. Ealum

Defense Mapping Agency
Washington, D.C.
(a) J.C. Harnack

EPA/EPIC
Warrenton, Virginia

EROS Data Center
Sioux Falls, S.D.
(a) J. Covert
(b) Library
(c) D.S. Linden
(d) L. Pettinger
(e) M.C. Kohde

Dr. John L. Estes
University of California
Santa Barbara, California

Euratom C.C.R.
Ispra (VA), Italy
(a) Library
(b) B.M. Sørensen

B. Fisher
ISIS Ltd.
Prince Albert, Saskatchewan
Canada

Elizabeth A. Fleming
Topo. Survey Directorate
Surveys & Mapping Branch
Ottawa, Ontario, Canada

J.J. Flynn
Department of Parks
Dayton, Ohio

F.A.O. United Nations
Rome, Italy
(a) R. Duda
(b) J.W. Mielkema

Bruce Forster
School of Surveying
Univ. New South Wales
Sydney, Australia

Dr. Kenneth E. Foster
Office Arid Lands Studies
University of Arizona
Tucson, Arizona

Gilbert V. Fraga
State Water Resources
Control Board
Sacramento, California

William D. French
Amer. Society Photogrammetry
Falls Church, Virginia

Norman L. Fritze
Rochester, New York

Nigel Gardner
Geography Department
University of Reading
Berkshire, United Kingdom

Lawrence M. Gatto
US Army CRREL
Manover, New Hampshire

Dr. Harold W. Gausman
U.S. Dept. Agriculture
Weslaco, Texas

General Electric Company
Space Division
Beltsville, Maryland
(a) W.L. Heydt
(b) A.B. Park

Geographisches Institut
Zurich, Switzerland
(a) K.I. Itten
(b) D. Steiner

Goddard Inst. for Space Studies
New York, New York
(a) V. Gornits
(b) W. Wilson

Dr. Harold M. Goldstein
General Electric Company
Philadelphia, Pennsylvania

Dr. A. Gonzalez S.
Ministerio de Energia y Minas
Caracas, Venezuela

Rafael R. Gotera
Natural Resources Management
Center
Owson City, Philippines

David M. Green
Cornell Field Station
Richfield Springs, New York

Dr. Clifford W. Greve
Autometric Inc.
Falls Church, Virginia

Dr. Frank Gumba
Dept. of Soil Science
University of West Indies
St. Augustine, Trinidad

Dr. Fred J. Gunther
Computer Sciences Corporation
c/o NASA-GSFC
Greenbelt, Maryland

Norman M. Gutlove
Fairchild Camera & Instrument
Syosset, New York

Prof. Barry M. Haack
Dept. of Geography
Ball State University
Muncie, Indiana

R.E. Haberman
Human Education Research &
Development Foundation
Portland, Oregon

Mike Hall
Ithaca, New York

R.J. Hall
Edmonton, Alta., Canada

Dr. R.S. Hammerschlag
Ecological Service Lab.
National Park Service
Washington, D.C.

Hardy Associates, Ltd.
Calgary, Alberta, Canada

D. Cook Harker
Tech. Resources Branch
Alberta Agriculture
Lethbridge, Alberta, Canada

Maurice B. Harrison
Bernard Lodge Factory
Spanish Town, Jamaica, W.I.

William Harting
Tri-State Regional Planning
Commission
New York, New York

Dr. Hassan M. Hassan
Survey Department
Khartoum, Sudan

Prof. F.M. Henderson
Dept. of Geography
SUNY at Albany
Albany, New York

Dr. William F. Herget
U.S. Environmental
Protection Agency
Research Triangle Park, N.C.

Dr. G. Daniel Hickman
Applied Science Technology
Arlington, Virginia

L. Hobbs
Smithsonian Institution
Washington, D.C.

Ir. J.A.C. Mollie
WINARS Bibliotheek
Wageningen,
The Netherlands

Dr. James P. Mollinger
Naval Research Laboratory
Washington, D.C.

Mr. R. Michael Nord
General Research Corp.
Washington Operations
McLean, Virginia

Asseblman William B. Hoyt
Legislative Commission
Science & Technology
Albany, New York

Prof. Shin-ya Nsu
Department of Geography
SUNY at Binghamton
Binghamton, New York

Indian Photointerpretation
Institute (INSA)
Dehra Dun, India

Dr. Yngvar W. Isachsen
M.Y.S. Geologica: Survey
Albany, New York

Dr. Suresh C. Jain
Monteg Ltd.
Concord, Ontario
Canada

Dennis Jaques
Environmental Sciences Ctr.
University of Calgary
Calgary, Canada

M. Jayaraman
U.T. Space Institute
Tullahoma, Tennessee

Homer Jensen
Aero Service Division
Elkins Park, Pennsylvania

William Johnston
Essex County Planning
Office
Elizabethtown, New York

Z.D. Kalensky
Dept. de Photogrammetrie
Universite Laval
Quebec, Canada

D.S. Kanat
Space Applications Ctr.
Ahmedabad, India

Herbert Kaplan
Barnes Engineering Co.
Stamford, Connecticut

Dr. Kardono
Bakosurtanal, Cibinong,
West Java, Indonesia

Robert Kasvinsky
New England River Basins
Commission
Boston, Massachusetts

S. Kears
American Agriculturist
Ithaca, New York

Prof. William C. Kennard
Department of Plant Science
University of Connecticut
Storrs, Connecticut

Prof. Ralph W. Kiefer
University of Wisconsin
Madison, Wisconsin

Dr. Vytautas Klenas
College of Marine Studies
University of Delaware
Newark, Delaware

Ellis Koch
Suffolk County Dept. of
Environmental Control
Hauppauge, New York

Dr. B.N. Koopmans
ITC
Enschede, The Netherlands

Dr. Lee E. Koppelman
Suffolk Co. Dept. Planning
Hauppauge, L.I., New York

Dr. John D. Koutsandreas
U.S. Environmental Protection
Agency
Washington, D.C.

William S. Kowalik
School of Earth Sciences
Stanford University
Stanford, California

Dr. Richard J. Kramer
Brookfield, Wisconsin

Raymond Kreig
Anchorage, Alaska

Dr. J.V. Kuilenburg
Netherlands Soil Survey Inst.
Wageningen, Netherlands

M.H. Kuyper
Florida Dept. Transportation
Tallahassee, Florida

S. Laliberte
Ministere des Terres et Forets
Ste-Foy, Quebec, Canada

E.J. Langham
National Hydrology Research
Institute
Ottawa, Ontario, Canada

Dr. Germain LaRoche
Site Safety & Envir. Analysis
U.S. Nuclear Regulatory Com.
Washington, D.C.

Prof. Bruce L. LaRose
Cartography-Geography Dept.
Pace University
Pleasantville, New York

R.H. Lefebvre
Geology Department
Grand Valley State Colleges
Allendale, Michigan

Leonard A. LeSchack
Silver Spring, Maryland

LGL Ltd. Environmental
Research Association
Edmonton, Canada

Harry L. Loats, Jr.
Ecosystems International
Gambrills, Maryland

Katherine S. Long
U.S. Army Eng'r. Waterways
Experiment Station
Vicksburg, Mississippi

Prof. Walter K. Long
Cayuga Museum History and Art
Auburn, New York

Dr. Arthur P. Loring
York College
City Univ. of New York
Jamaica, New York

Dr. Ray Lougeay
State University College
Department of Geography
Geneseo, New York

Raymond Lowry
Intera Environ. Consultants
Ottawa, Ontario, Canada

Alex R. Mack
Land Resource Research
Institute
Canada Dept. of Agriculture
Ottawa, Ontario, Canada

F.B. MacKay
Marshall Macklin Monaghan, Ltd.
Don Mills, Ontario, Canada

L.A. Maercklein
N.Y.S. Dept. Transportation
Albany, New York

R.C. Maharana
Directorate of Mines ORISSA
Bhubaneswar, India

Dr. Allan Marmelstein
U.S. Fish & Wildlife Service
Washington, D.C.

Don B. Martin
Monroe County Department
of Planning
Rochester, New York

Prof. Lawrence R. Matson
Earth Sciences/Geology
Ulster Co. Community College
Stone Ridge, New York

Dr. Paul M. Maughan
COMSAT General
Washington, D.C.

Kenneth H. Mayhew
N.Y.S. Board of Hudson River
Black River Regul. District
Watertown, New York

Samuel W. McCandless, Jr.
User Systems Engineering
Annandale, Virginia

Ralph McClure
O'Brien and Gere Engineers
Syracuse, New York

Donna McCool
Washington State University
Pullman, Washington

Dr. Roger M. McCoy
Department of Geography
University of Utah
Salt Lake City, Utah

Prof. Jerry N. McDonald
Department of Geography
Radford University
Radford, Virginia

Rex McHail
Rausch and Lomb, Inc.
Rochester, New York

Randy A. McKinley
Beloit, Kansas

Jay McLeester
Konski Engineers
Syracuse, New York

Dr. Roy A Mead
Dept. Forestry & Forest Prod.
Virginia Polytechnic Institute
Blacksburg, Virginia

Michigan State University
East Lansing, Michigan
(a) M. Enslin
(b) M. Karteris
(c) R.L. Shelton

Prof. E.M. Mikhail
Purdue University
School of Civil Engineering
West Lafayette, Indiana

Dr. Lee D. Miller
Remote Sensing Center
Texas A & M University
College Station, Texas

Dr. Edward Mills
Cornell Field Station
Bridgeport, New York

Prof. Olin Mintzer
Ohio State University
Civil Engineering
Columbus, Ohio

Dr. Senen M. Miranda
Philippine Council for Agr.
& Resources Research
Los Banos, Philippines

Harry Missirian
Tompkins County Dept. Planning
Ithaca, New York

Echo Mitchell
West Central Regional
Development Commission
Fergus Falls Community College
Fergus Falls, Minnesota

Dr. Steven J. Mock
U.S. Army Research Office
Research Triangle Park, N.C.

Dr. John D. Mollard
J.D. Mollard and Associates
Regina, Saskatchewan, Canada

Dr. Richard Monheimer
N.Y.S. Education Dept.
Albany, New York

Monroe County ZMC
Rochester, New York

Dr. Donald G. Moore
Remote Sensing Institute
South Dakota State Univ.
Brookings, South Dakota

Dr. Stan Morain
University of New Mexico
Albuquerque, New Mexico

Dr. David L. Morgan
Sackville, Nova Scotia
Canada

James Morton
N.Y. Dept. of State
Albany, New York

Alan P. Muir
Columbia Co. Planning Board
Hudson, New York

Dr. Larry C. Munn
Dept. Plant & Soil Science
Montana State University
Bozeman, Montana

Timothy J. Murphy
Cooperative Extension of
Warren County
Warrensburg, New York

Prof. Peter A. Murtha
Faculty of Forestry
Univ. British Columbia
Vancouver, B.C., Canada

Dr. Robert Nagler
System Planning Corp.
Arlington, Virginia

NASA Goddard Space Flight
Center
Greenbelt, Maryland
(a) L.J. Allison
(b) J.L. Barker
(c) B.G. Bly III
(d) P.J. Cressy, Jr.
(e) D.K. Hall
(f) S. Levitas
(g) B.L. Markham
(h) V. Salomonson
(i) T. Schmugge
(j) N.M. Short
(k) L.L. Thompson

NASA Headquarters
Washington, D.C.
(a) M. Calbrese
(b) M. Felsler
(c) P.G. Thome
(d) J.A. Vitale

NASA Langley Research Center
Hampton, Virginia
(a) D. Bartlett
(b) W.E. Bressette
(c) J.B. Hall
(d) R.W. Johnson

NASA Lewis Research Center
Cleveland, Ohio
(a) R.L. Bowman
(b) R.J. Schertler
(c) E.W. Spizz

Nat'l. Remote Sensing Agency
Hyderabad, India
(a) B.S. Ayyangar
(b) R. Deekhatulu
(c) N.C. Gautam
(d) J.D. Murti
(e) K.R. Rao
(f) P.S. Rao

NOAA/NESS
Washington, D.C.
(a) E.L. Heacock
(b) E.R. Hoppe
(c) W.A. Hovis
(d) J.H. Liensach
(e) C.A. Spohn
(f) A.E. Strong
(g) M.P. Waters
(h) D.R. Wiesnet

NOAA/Nat'l. Ocean Survey
Washington, D.C.
(a) N.E. Banks
(b) W.V. Hull
(c) A. Malahoff

N.Y.S. Adirondack Park
Agency
Ray Brook, New York
(a) R.P. Curran
(b) G.A. Hill

N.Y.S. Agricultural Experiment
Station
Geneva, New York

N.Y.S. Dept. of Environmental
Conservation
Albany, New York
(a) I. Carcich
(b) E. Fried
(c) J. Harmon
(d) L.J. Hettling
(e) P.R. Sauer

N.Y.S. Dept. of Health
Albany, New York
(a) W.C. Ahearn
(b) G.W. Fuhs
(c) C.S. Kim

N.Y.S. Office of Parks and
Recreation
Albany, New York
(a) P.J. Buttner
(b) I.P. Vamos

N.Y.S. Public Service Comm.
Albany, New York
(a) F. Burggraf
(b) W. Litley

N.Y. Wetlands Inventory
Albany, New York

Carl Nielsen
Seattle, Washington

Paul O'Connor
Fulton Co. Planning Dept.
Johnstown, New York

Dr. Charles E. Olson
University of Michigan
School of Natural Resources
Ann Arbor, Michigan

Prof. Joseph Otterman
Dept. of Environ. Sciences
Tel Aviv University
Ramat-Aviv, Israel

Dr. Robert Oudemans
Bakosurtanal
Jakarta, Indonesia

Dr. Daniel Palm
St. Lawrence-Eastern
Ontario Commission
Watertown, New York

David Robb
St. Lawrence Seaway Development Corporation
Washington, D.C.

Rome Air Development Center
U.S. Air Force
Griffiss A.F.B., New York
(a) K.A. Butters
(b) E.E. Hicks

Caren Rubin
Falls Church, Virginia

Dr. Robert D. Rudd
Geography Department
University of Denver
Denver, Colorado

Donald C. Rundquist
Remote Sensing Laboratory
University of Nebraska-Omaha
Omaha, Nebraska

Ann E. Russell
Berkeley, California

Roy Russell
Ministry of Agriculture
Hope Gardens, Kingston
Jamaica

Dr. Floyd Sabins, Jr.
Chevron Oil Field Research Co.
La Habra, California

Dwight A. Sangrey
Dept. of Civil Engineering
Carnegie-Mellon University
Pittsburgh, Pennsylvania

Patricia Sarsfield
Fairfax, Virginia

Dr. L. Sayn-Wittgenstein
Dendron Resource Surveys Ltd.
Ottawa, Ontario, Canada

Martin Schildkret
M.S. News Service
Brooklyn, New York

Dr. Carlos O. Scoppa
Buenos Aires, Argentina

Michael E.A. Shaw
Sugar Industry Research
Mandeville, Jamaica, W.I.

Gary A. Shelton
U.S. Envir. Protect. Agency
Envir. Monitor & Support Lab.
Las Vegas, Nevada

Dr. Barry Siegel
Ebasco Services, Inc.
Greensboro, North Carolina

Dr. C. Sinclair
Commonwealth Forestry Bureau
Oxford, England

Robert Sivers
Sciences-Engineering Library
University of California
Santa Barbara, California

Robert M. Skirkanich
Grumman Data Systems
East Northport, New York

Vernon R. Slaney
Geological Survey of Canada
Ottawa, Ontario, Canada

Harry E. Smail
Battelle, Columbus Labs.
Columbus, Ohio

Lawrence Smith
Albany County Planning Board
Albany, New York

William L. Smith
Spectral Data Corp.
Arlington, Virginia

Anthony Smyth
Ministry Overseas Development
Surrey, Surrey, England

E. Mayo Snyder
Otsago County Plan. Dept.
Cooperstown, New York

G. William Spann
Atlanta, Georgia

Dr. Robert L. Talerico
USDA, Forest Service
Broomall, Pennsylvania

Sotaro Tanaka
Remote Sensing Technology
Center of Japan
Tokyo, Japan

Paul Tessar
National Conference State
Legislatures
Denver, Colorado

Texas Dept. Water Resources
Austin, Texas

Cpt. Paul Thies
U.S. Army Environmental
Hygiene Agency
Aberdeen Prov. Grds., Md.

S. Thiruvengadasachari
Andhra Pradesh, India

S. Thyagarajan
Capital District Regional
Planning Commission
Albany, New York

Dr. Heng L. Thung
Ithaca, New York

William J. Todd
Ames Research Center
Moffett Field, California

Richard J. Tourin
Stone & Webster Eng'g. Corp.
New York, New York

Earl J. Tullios, Jr.
Cotton Incorporated
Raleigh, North Carolina

David Tyler
Dept. of Civil Engineering
University of Maine
Orono, Maine

U.S. Army Engr. Topo. Labs.
Fort Belvoir, Virginia
(a) R.D. Leighty
(b) G.E. Lukes

Dr. Spiers, U.N.D.P.
Land & Water Use Planning
Maputo, Mozambique

Dr. Donald B. Stafford
Dept. of Civil Engineering
Clemson University
Clemson, South Carolina

Dr. Pierre St.-Amand
Naval Weapons Center
China Lake, California

SUNY College
Dept. of Geography
Oneonta, New York
(a) P. Baumann
(b) T.J. Gergel

SUNY College of Environ.
Science & Forestry
Syracuse, New York

SUNY College of Environ.
Science & Forestry
Syracuse, New York
(a) R.H. Brock, Jr.
(b) M.J. Duggin
(c) J. Felleman
(d) J.J. Flynn
(e) P. Hopkins
(f) D. Monteith

Donald M. Stone
American Institute of Aeronautics & Astronautics
Los Angeles, California

Al Stringham
Land Care, Inc.
Boonville, New York

Robert A. Summers
Office of Int'l. Affairs
Washington, D.C.

Dr. Sutanto
Fakultas Geografi
Universitas Gadjah Mada
Yogyakarta, Indonesia

Karl-Heinz Szekielda
United Nations, New York

Dr. Dennison Parker
U.S. Fish & Wildlife Service
Fort Collins, Colorado

Dr. A.J. Parsons
Dept. of Geography
Keele University
United Kingdom

David Parsons
Tampa, Florida

P.A.R. Corp.
Rome, New York
(a) G.J. Kinn
(b) J. Lemmer
(c) M. Zoracki

Dr. Eugene L. Peck
NOAA National Weather Service
Silver Spring, Maryland

F.G. Peet
Ottawa, Ontario, Canada

Pennsylvania State University
University Park, Pennsylvania
(a) G.W. Marks
(b) G.J. McMurtry
(c) G.W. Petersen

Frank Perchalski
TVA
Chattanooga, Tennessee

Prof. Elmer S. Phillips
Ithaca, New York

Dr. Kenneth R. Piech
SCIPAR
Buffalo, New York

Peter Playfoot
Bausch & Lomb Canada
Don Mills, Ontario, Canada

Kamila Plesmid
Humboldt State University
Center for Community Devel.
Arcata, California

Dr. Richard Protz
University of Guelph
Land Resource Science
Guelph, Ontario, Canada

Purdue University L.A.R.S.
West Lafayette, Indiana
(a) R.M. Hofter
(b) K. Latz
(c) D.B. Morrison
(d) C.E. Seubert

Robert D. Purvis
Crosby, Mississippi

Pat Quigley
Philadelphia, Pennsylvania

Bob Quinn
Tug Hill Commission
Watertown, New York

Dr. George A. Rabchevsky
Kensington, Maryland

Dr. Rene O. Ramseier
Surveillance Satellite Project
Office
Ottawa, Ontario, Canada

Dr. V.R. Rao
ISRO Headquarters
Bangalore, India

John Razzano
U.S.G.S./W.R.D.
Albany, New York

Porter Peed
National Wetlands Inventory
St. Petersburg, Florida

Robert J. Reed
Tulsa, Oklahoma

Dr. Harold T. Rib
Federal Highway Admin.
U.S. Dept. Transportation
Washington, D.C.

Dr. Benjamin F. Richason
Department of Geogzaphy
St. Cloud University
Saint Cloud, Minnesota

Fred Riddle
Pasadena, California

Maureen A. Ritchie
Philadelphia, Pennsylvania

U.S. Dept. of Agriculture
Soil Conservation Service
Syracuse, New York

U.S. Dept. of Agriculture
ESCS
Washington, D.C.

(a) G.A. Hanuschak
(b) R. Sigman
(c) M.H. Wigton

U.S. Dept. of Energy
Washington, D.C.
(a) G.E. Courville
(b) J.J. Cuttica
(c) R.A. Summers

U.S. Forest Service
Atlanta, Georgia
(a) W.H. Clerke
(b) W.H. Padgett

U.S. Geological Survey
Boulder, Colorado
(a) R.H. Alexander

U.S. Geological Survey
Flagstaff, Arizona
(a) J.R. Nation

U.S. Geological Survey
Reston, Virginia
(a) J.R. Anderson
(b) V. Carter
(c) M.D. Carter
(d) W.R. Hemphill
(e) Librarian
(f) R.B. McEwen
(g) L.C. Rowan
(h) P.G. Teleki
(i) R.S. Williams, Jr.
(j) J. Wray

Univ. of Kansas
Lawrence, Kansas
(a) E.A. Martinko
(b) J.W. Merchant

Univ. of Maryland
Eastern Shore
NASA Wallops Flight Center
Wallops Island, Virginia

Univ. of Massachusetts
Amherst, Massachusetts
(a) Remote Sensing Center
(b) K.A. Richardson

Univ. of Minnesota
St. Paul, Minnesota
(a) W. Johnson
(b) T.M. Lillesand

Dr. J.L. van Genderen
Fairrey Surveys Ltd.
Maidenhead, Berkshire, UK

Robert W. Wade
U.S. Army Corps Eng'gs.
Buffalo, New York

William H. Walker
Creative Communications
Services
Pittsford, New York

Dr. Douglas S. Way
Dept. Landscape Architecture
Harvard University
Cambridge, Massachusetts

Dr. Richard Webster
ARC Need Research Organization
Yarnton, Oxford, England

Dr. Stanley C. Wecker
Department of Biology
The City College
New York, New York

Edward Wedler
St. John's, Newfoundland,
Canada

Richard A. Weigand
Austin, Texas

Robert S. Weiner
University of Connecticut
Department of Geography
Storrs, Connecticut

Carolyn C. Weiss
Statistics Canada, Census
Ottawa, Ontario, Canada

Prof. Roy A. Weich
Department of Geography
University of Georgia
Athens, Georgia

Westinghouse Electric Co.
Baltimore, Maryland
(a) J.A. Hall
(b) M.J. Spangler

ORIGINAL PAGE IS
OF POOR QUALITY



Kevin A. Wheeler
USDA Soil Conser. Service
Canton, New York

Dr. Gary Whiteford
Univ. of New Brunswick
Faculty of Education
Fredericton, N.B., Canada

G.N. Wickware
Lands Directorate
Burlington, Ontario
Canada

Phoebe Williams
NASA Ames Research Center
Moffett Field, California

Joseph A. Winsky
Los Angeles, California

Prof. Kam W. Mong
University of Illinois
Dept. of Civil Engineering
Urbana, Illinois

Woodward-Clyde Consultants
Clifton, New Jersey
(a) R. Hinkle
(b) J.R. Lovegreen

Woodward-Clyde Consultants
San Francisco, California
(a) C.A. Kitcho

Woodward-Clyde Consultants
St. Louis, Missouri
(a) W. Prosser

Dr. Guirguis F. Yassa
Sussex, New Jersey

Prof. Edward F. Yost, Jr.
Science Eng'g. Research Group
Long Island University
Greenvale, New York

Dr. Linda S. Zall
Earth Satellite Corporation
Washington, D.C.